

*Phelsuma*

Volume 8

ISSN 1026-5023

2000



## EDITORIAL

This 8<sup>th</sup> edition of *Phelsuma* covers a wide range of animal and plant species, looking at diverse aspects of taxonomy, ecology and conservation. There are few points in common between them beyond a general tendency towards restricted distributions. Of these species, several are of conservation concern in the region, although only two are currently listed as threatened by the IUCN. It has proved difficult to develop conservation approaches for most of the other species, largely because they are not presently considered to be 'globally threatened'. In the case of the tree *Brakophanium 'mouligascorivum'* (Moraceae) this is because the critically endangered species is currently, but unsuitably, synonymised with a widespread tree. The terrapin *Pelomedusa subveter parvitalis* (Pelomedusidae) is not listed because current taxonomy recognises it as an endemic subspecies, a taxonomic level that is included in the IUCN Red List for plants, but not for animals, a purely arbitrary distinction.

The conservation priorities given to different species are largely derived from their presence or absence on the IUCN Red Lists, these only consider globally threatened species and so a threatened population of a widespread species will not be listed. In terms of evolutionary biology and conservation of genetic diversity all populations are of conservation significance. Exclusion of locally threatened populations is purely derived from global biodiversity conservation perspectives, perspectives that have come to be dominant due to the geo-political interests of major international NGOs. For local conservation this diversifies natural ecosystem conservation into the priorities of global politics while putting locally threatened gene pools and ecosystems at risk. The emphasis on endemic taxa fails to recognise taxonomic uncertainty, genetic population units and non-endemic keystone taxa.

For conservation to be sustainable it needs to be focused on a regional, national or local ecosystem level. Unless conservation has a local genesis it is unlikely to prevent deterioration of evolutionarily resilient ecosystems and biodiversity loss will continue. The only systems to benefit are those containing species meeting the global priorities of the international NGOs, priorities which are arbitrary in respect to ecology.

The imposition of international NGO politics into the region's conservation efforts currently distorts funding options and represents a major threat to sustainable conservation. It is to be hoped that the developing dissatisfaction with these priorities and politics will result in a more realistic conservation approach. The Nature Protection Trust of Seychelles has always held this approach to be essential and continues to emphasise that conservation must be local in origin and local in action even though funding cannot always be truly local.

J Gerlach  
Editor

## CHAIRMAN'S REPORT

On 31st October 1999 our information centre and laboratory on Silhouette island was opened. Fifty people attended the short and informal ceremony which was followed by a superb lunch at the Silhouette Island Lodge. Although none of the major sponsors of the building were able to attend, NPTS members, a visiting group from the British Chelonia Group, guests from the Lodge and the press were present. Television coverage by Seychelles Broadcasting Corporation reporter Kevin Malbrook was well thought out and presented and the opening made headline news.

Since the opening, the information centre has proved to be a valuable asset for both the Silhouette Conservation Project and the Tortoise and Terrapin projects. It is on the itinerary for almost all visitors to Silhouette and affords us an opportunity to explain the wider biological importance of the island to them. They are also able to view our collection of biological specimens and inspect at close quarters creatures they may have only seen fleetingly in the forest.

The Silhouette Conservation Project received a moral boost this year when we were asked to co-ordinate a project for forest conservation on the island. A project that had not received funding when submitted under the Seychelles Government's National Biodiversity Action Plan had been submitted by the Division of Forestry and named the NPTS and Islands Development Company (IDC) as participants. We were asked to resubmit this project in greater detail in March 1999 as it was considered by the World Bank's Global Environment Facility (GEF) as "potentially eligible" for funding. The project was re-written to incorporate many of the main aims of the NPTS. Its slow passage through Government prior to re-submission to the GEF has meant that at the time of writing (May 2000) it has still not reached the funding body.

Our Seychelles Giant Tortoise Conservation Project now has a full complement of *Droghda arnoldi* tortoises. We were able to purchase the last remaining female from the Bougainville Hotel here, and Akda, as she is called, brings us up to three females and three males. The largest female, Clio, produced two clutches of eggs last season but they did not hatch, for reasons unknown.

The project was the subject of a film made for American television during the year. The film is part of a series on people working with endangered species, and will, we hope, bring our project to a wider audience.

We had a major success with the Seychelles Terrapin Conservation Project when a single hatchling was produced on 31st March 2000. The problems experienced over the last two seasons persist, with eggs being laid in the ponds instead of on the land. We have, however, solved the incubation problems and if we "rescue" the eggs soon enough, they will hatch. The new enclosures and tanks are a great improvement on the earlier accommodation but we are still in need of two pumps to circulate the water.

Roche Causse Bird Sanctuary continues to be a major headache for us, as it is subject to continual vandalism. We have also not been able to deal with the problem of the large number of huge Casuarina trees that are a menace to the fence because of their shallow roots. Vegetation management within the sanctuary has also had to be curtailed because for the last 12 months there has been no herbicide on the market.

Without the encouragement and support, both financial as well as in kind, of the fol-

following organisations and individuals, some of our projects would be possible:  
Islands Development Company - Premises and logistical support  
Dr J Steinbacher and "Gefiederte Welt" - Donations  
Air Seychelles - Transport of equipment for Info Centre  
British Chelonia Group - Giant Tortoise Project equipment  
Mr William Patrick Watson - Donations  
Pool & Patel - For acting as our honorary auditors.

To you all, very many thanks. We would also like to thank the many individual donors and supporters who have made smaller but equally significant donations during the year.

Finally a word of thanks to the kind people who have, at their own expense, acted as conservation volunteers for us this year. They include Anne & Bill Truscott, Deryll Birch, Frankie Hobbs, Tara Corina, Ken Jordan, Jasmine Gurbux, Lala Gregorek and Richard Pitman.

R. Gerlach  
Chairman

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## NPTS SCIENTIFIC COMMITTEE

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Appropriate members of the Scientific Committee have provided comments for the development of the NPTS 'Policy on Re-introductions'. This has been based very closely on the IACIN Re-introduction Specialist Group's 'Guidelines for Re-introductions' and provides a scientific basis for any re-introductions which the NPTS is involved with in the future.

Some members of the committee have also commented on the proposal for a major project to assess the biodiversity of all of the Seychelles islands. Although this is not specifically an NPTS project it ties in with our aims and its first field stage will be based on Silhouette, using NPTS facilities there. This project is reported on separately.

The committee has continued to be involved with proposing contingency plans for the rat eradication project on Fregate island. Particular concerns were raised over the toxic effects of Brodifacoum poison on the island's endemic reptiles (see p 79). The Division of Environment has been persuaded of the significance of this problem and has accepted the need for securing the future of these species.

J. Gerlach

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## ROCHE CAIMAN BIRD SANCTUARY

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There have been no significant developments with the Roche Caiman Bird Sanctuary, vandalism continues and the unstable Casuarina trees threatening the fence remain. It has proved impossible to manage the re-growth of roads in the sanctuary due to a lack of herbicide in Seychelles for the last 12 months.

The Bird Sanctuary continues to be used by black-crowned night-herons, grey herons, green-backed herons and roseateas.

R. Gerlach

## SEYCHELLES GIANT TORTOISES

A great achievement for the Seychelles Giant Tortoise Conservation Project in 1999 was the purchase of the last remaining *Daprosochelys arnoldi* female from the Boganville Hotel herd. This female, Alida, brings us up to 3 female and 3 male *D. arnoldi*. Alida has settled in well but as with the other tortoises from the Boganville Hotel it is doubtful whether she will ever fully recover from decades of neglect. The prospects for the future of *D. arnoldi* remain with Stan and Chlo. As reported last year Chlo laid her first clutch of eggs in July 1999. A second clutch followed in September but, unfortunately, none of these eggs hatched. It is quite common for captive tortoises to lay infertile clutches before producing viable eggs and we hope that the 2000 season will result in success.

There have been no new developments in the *D. hololoma* herd.

In August 1999 the project was the subject of a documentary film made by RAMM Entertainment in Amsterdam, for world-wide distribution. The tortoises were also visited by a tour group from one of the project's largest sponsors, the British Chelonian Group.

Both surviving Seychelles species are fully described in the new CD-ROM version of 'Turtles of the World' - the standard reference on turtles, tortoises and terrapins. There are photographs of Adrian and Claron, representing *D. arnoldi* and *D. hololoma* respectively. Other publications on the tortoises are listed below.

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J. Gerlach

## SEYCHELLES TERRAPINS

1999 has been a very poor year for Seychelles terrapins in general. The drainage of the Anse Karlan marsh on Praslin saw the destruction of the largest remaining population of *Pelusios subreigeri* and a significant *P. castaneoides* population. The loss of this site now means that both species are restricted to some 200 surviving individuals, and both species must be virtually extinct on Praslin. The drainage received no prior publicity which was particularly unfortunate as we lost the chance to rescue the terrapins before drainage. This could have enabled reintroductions to other sites, but instead it makes successful captive breeding even more urgent than before.

This year we are able to report some success from our captive breeding project. The first ever successful captive hatching of a Seychelles terrapin (*P. subreigeri*) occurred on 31st March 2000. As with last year all the eggs were laid in the water, but two were found before they drowned. Of these one hatched, this success is reported on in full detail elsewhere in this issue of 'Phelsuma'.

There has been no sign of breeding in the *P. castaneoides* ponds. Conditions are presumably still not ideal but this may be overcome if we can obtain more pumps to keep the water flowing for this riverine species.

J. Gerlach

## SILHOUETTE CONSERVATION PROJECT

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As noted in the Chairman's Report the Silhouette Conservation Project's information centre and laboratory was opened on 31st October 1999. This building houses information displays describing the work of the NPTS, the Silhouette project and the biodiversity and ecosystems of Silhouette. It also incorporates our display specimens and taxonomic reference collections. The back part of the building is a laboratory area for use in research work associated with the Silhouette, Tortoise and Terrapin Projects. The information centre has been visited by most of the visitors to Silhouette since its opening and has proved to be a great asset in providing information to visitors.

A visit to Silhouette by RAMM Entertainment in August 1999 to film a documentary on the tortoises was so successful that the footage they obtained has been extended into a second film specifically about the Silhouette Conservation Project.

Plans for conservation work on Silhouette continue to be developed and a major initiative is being prepared as part of a proposal being submitted to the World Bank's Global Environment Facility (GEF) by the Division of Forestry. This will make a great difference to our work on Silhouette if funding is approved. In the meantime small scale management continues in selected areas.

J. Gerlach

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## INDIAN OCEAN 2000-2005

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A project to assess the biodiversity of the Seychelles and Mauritian islands in commemoration of the centenary of the Percy Sladen Trust Expedition to the Indian Ocean



In 1905 and 1906-9 the Percy Sladen Trust Expedition visited the islands of the western Indian Ocean to investigate the biological relationships between the islands of the Seychelles, Mascarenes and Chagos groups and to locate evidence for former land connections between the islands. This expedition still forms the basis of our understanding of the region's biogeography with the recognition that the granitic Seychelles islands are continental fragments of Gondwana, isolated from India and Madagascar 65 million years ago whilst the other islands are volcanic in origin. The continental history of the granitic islands results in a diverse and archaic fauna, with more recent immigrant taxa of African, Malagasy or cosmopolitan origin. The Mascarenes, Amirantes, Aldabra and Chagos island groups all support immigrant taxa with affinities resulting from the predominant marine currents.

Western Indian Ocean biogeography is of great interest due to the combination of the influences of dispersal and vicariance over a large geographical area and to the retention of

archaic taxa recognizable as family-level endemics or as combining features of distinct families characteristic of both the Indian and Afro-Malagasy regions. Despite their ecological and evolutionary significance, the islands have received relatively little attention since the Percy Sladen Trust Expedition. The smaller Mascarene islands are still virtually unexplored from a biological perspective and the Percy Sladen Trust Expedition remains the most extensive study of the Seychelles islands. Since 1909 there have been a small number of small-scale expeditions, visiting 31 islands, of which only 12 have been studied in detail. The remaining 84 have not been studied with the exception of individual visits to record reptiles and birds. Collections made in the 1990s indicate the occurrence of significant faunal changes in recent years resulting from continued colonisation from Madagascar and invasion by alien species.

There is a need to review the current biodiversity of the islands to determine the conservation status of the region's biodiversity and to investigate the balance of colonisation and extinction over the last 100 years. The conservation requirements of the islands are pressing due to the expansion of development on the islands, the decline of historical land management practices and the spread of alien species.

The 'Indian Ocean 2000-2005' project will survey the terrestrial and fresh-water biodiversity of all 115 Seychelles islands and the unvisited off-shore islands of Maubius. This international project, timed to be completed for the centenary of the Percy Sladen Trust Expedition, would use thorough collecting techniques on each island to make representative collections of all animals, plants, lichens, fungi and protists on each island, including surveys of important, but neglected, parasites. For many of these groups this will be the first systematic study in the region. The project will provide the data required to locate important biodiversity sites, identify areas and taxa of concern and evaluate the current distribution of alien species and their spread over the last 100 years. Surveying the islands that remain uncollected will fill in the main gaps in our knowledge of the region's biodiversity and facilitate interpretation of the biogeographical patterns. This will provide a unique resource for the study of island biogeography as both the largest and the only complete data-set for all taxa and all islands in a single biogeographical region. The contrasts between oceanic and continental islands and the historical comparison available for some of the islands will make these records of exceptional significance. These data are needed to further scientific knowledge of the region, to plan appropriate conservation measures and to ensure that development can be environmentally sensitive in important biodiversity sites.

During the course of this project it is expected that many new animal species will be discovered. The contribution of the project's major sponsors will be recognised by naming new species after them. This will provide a permanent testimony to their essential and far-sighted support for science and conservation.

J. Gerlach

## FREGATE ISLAND INVERTEBRATES

The Fregate Island Invertebrate Programme at the Zoological Society of London

Good progress has been made since the last article was written in *Phelsuma* (May 1999). In September 1999 wild caught stock was collected from Fregate Island and transferred to the Invertebrate Conservation Unit at London Zoo to join the captive breeding programme. This consisted of twenty of each of the following species, giant Fregate beetle (*Polipogon herculeanus* Solier, 1848), giant millipede (*Seychellipus seychellanus* (Desjardins, 1834)), milk crab (*Pachyodius fregatae* Van Mel & Coppoys, 1980) and the scorpion (*Chromactis octopus* (Koch, 1838)). These were collected by The Nature Protection Trust of Seychelles with permission from the Seychelles government and the management of Fregate Island. These animals have settled in well and more details are given under the species headings.

### Fregate beetles *Polipogon herculeanus*

The number of Fregate beetles continues to increase at the zoo, with a grand total at present of over 230 adults. There is now a population of over 90 captive bred second generation beetles. These are being tagged after emerging so individuals can be monitored, and each one is measured to assess size variation throughout successive captive bred generations. These second generation beetles have produced numerous larvae which live in the enclosure substrate, we anticipate the third generation emerging very soon.

The 1999 collected stock (mentioned above) produced their first F1 generation adult beetle in early July. The substrate is full of larvae so no doubt many more will be emerging soon.

A number of the original 1996 wild caught adults are still alive, these are at least four and a half years old now. Some of these were kept in a mixed generation group but we have now separated them and put all the originals together to see if they are still capable of breeding at this age (the females at least, as it is not known whether the females store sperm or need to mate repeatedly this experiment will not tell us any conclusive data on whether the males are still fertile).

One new area of research has been stimulated by the finding that some of the beetles which have died have been infected with a fungus, identified as *Metarrhizium anisopliae* var *anisopliae*. This is a known entomopathogen and is used in biological control programmes of insects. As no biocontrol agent of invertebrates has been used in the Invertebrate Conservation Unit at the Zoo, and this fungus has not presented itself in any other stock, it is possible that the original adults were infected with this fungus before arriving at the Zoo. It has to be said that fortunately, this bio-control is not particularly virulent in Fregate beetles as the mortality rate in the population is low and not all deaths are attributed to this organism. Nevertheless its presence is important and all the historic post mortem information is being re-processed in order to find out more about this. It would also be valuable to investigate whether this biocontrol has been used on Fregate, or other islands in the Seychelles, in the past. There is a possibility it has been used on rhino beetles (*Oryctes monoceros* (Olivier, 1789)) in coconut plantations, although there is no documented record of its use.



## Beetle snails

With continuing temperature control problems in the old invertebrate House the snails originating from those collected in 1996 at last potted out. The 1999 animals went straight into the new breeding room at the 'Web of Life' and are doing very well. They have produced an estimated 300 young, which are growing fast with some now at the sub-adult stage. One group is being kept as mixed generation (to increase numbers quickly), the other as separate generations (to maximise the retention of genetic diversity) in this way we get the 'best of both worlds' in terms of genetically managing the population in captivity.

## Millipedes

The offspring of the 1996 wild caught adults are just about adult size now. There are approximately 350 of these, they spend most of their time buried in the soil substrate and digging them up can cause damage (especially to those individuals which are molting), so accurate numbers are difficult to ascertain. The new 1999 stock has hatched, there are over 300 young at about 2cm in length.

## Scorpions

We were very pleased to receive these scorpions at the Zoo, as not only are they very handsome scorpions but this species has not been kept here before. Twenty were brought in, two adult males, two adult females and sixteen others at various juvenile stages. The adults are being kept as separate pairs, and mating has been observed with both pairs although no young have been produced as yet. The rest are being kept singly until they mature.

## Transfers to other Zoos.

As the Pringle Island beetles, snails and millipedes have done so well at ZSL we are in the fortunate position of being able to distribute animals to other conservation minded institutions interested in contributing to the captive breeding effort. Small groups of 1996 F1 beetles have gone to Bristol Zoo (12) and Poole Zoo (10). F1 Millipedes have gone to Ards Zoo (24), Bristol Zoo (60), and Poole Zoo (25). Snails have gone to Martin Mere (4 wild caught adults plus 40 F1 juveniles). This is a positive step as it is good practice to set up satellite groups in geographically isolated areas so if a disaster occurs in one collection, the species will survive in others.

We are in the process of preparing an updated report documenting details of the research carried out on these species at ZSL. This report will be produced by the end of the year. We are sure there will be some unique information revealed as well as areas highlighted where further investigations would be valuable.

Amanda Ferguson

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[S = grassie islands, Berl & Denis, Ann = Annamite, Ald = Aldabra]

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# Genetic fingerprinting of two endemics from the Seychelles - *Medusagynne oppositifolia* (Medusagynaceae) and *Rothmannia annua* (Rubiaceae)

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**Abstract:** Levels of genetic variation in two endemic woody species, *Medusagynne oppositifolia* from Mahé and *Rothmannia annua* from Anse, were studied using amplified fragment length polymorphisms (AFLP) fingerprinting and shown to be relatively low (5–7%). In *M. oppositifolia* six wild plants (five from the main population on Mt. Barrois and two more isolated plants from Copeña and Mt. Salier) were sampled, and these were compared to cultivated material of *M. oppositifolia* from Kew and Nancy. The sample from Mt. Salier was genetically the most distinct. Cultivated plants from both gardens had similar genotypes to plants from Mt. Barrois, although one plant from Nancy appeared to be slightly more distinct than the others in the POEA analysis. In *R. annua*, 28 samples collected on Anse were studied, and many individuals were genetically indistinguishable as they had no unique markers. These individuals (two from the same area and one isolated plant in the west) appeared to be relative genetic outliers. The results are discussed in terms of the conservation of the species.

**Keywords:** Anse, Mahé, AFLP, genetic fingerprinting, *Medusagynne oppositifolia*, *Rothmannia annua*

## Introduction

There is now a general consensus of opinion that management of rare and endangered taxa can be improved if it is informed by genetic data at various levels (Mace *et al.* 1996). In a world of limited resources isolated lineages should be accorded higher priority for conservation. Thus an endangered monotypic family such as Medusagynaceae (see below) has greater significance in terms of biodiversity than a rare subspecies of an otherwise common species, and this significance should be reflected in the establishment of conservation priorities (Viana-Wright *et al.* 1991). DNA sequencing allows us to investigate these issues by placing narrow endemics within a larger context (Fay *et al.* 1997, Chase & Fay 1997).

Within species, the loss of genetic variation is of major concern as it can preclude the ability of a species to respond to natural selection and consequently limit its evolutionary potential. In the long term, genetic variation can be a critical factor for persistence in a changing environment (Frankel & Soltis 1981, Lande & Barrowclough 1987). Small populations are often subject to the loss of alleles through genetic drift. Reduced population size can also result in inbreeding depression and a decline in population fitness caused by increased homozygosity and the unmasking of recessive deleterious alleles. As a result, the success of any genetic conservation programme is dependent on an understanding of the level and distribution of genetic variation present in the geopopul.

At the population level, DNA sequences are not generally variable enough to be informative and to acquire knowledge of the distribution of genetic variation within and be-

own populations, one of a range of techniques, collectively referred to as genetic fingerprinting, is often used to produce this important information. Genetic fingerprinting involves the production of a set of DNA fragments which reflects the genetic constitution of an individual. These fragments can be visualised as bands in gel electrophoresis using radioactivity, silver staining or fluorescent dyes to label the DNA. For a fuller discussion of the different molecular techniques for studying population genetics, see Qamaruz-Zaman *et al.* (1998a).

One of the first methods to be developed was restriction fragment length polymorphism (RFLPs). However, this technique is not appropriate for use with rare species or small populations since it requires relatively large amounts of DNA and, hence, also a large quantity of leaves or other plant material.

In the nineteen nineties, genetic fingerprinting techniques incorporating the technology of the polymerase chain reaction (PCR) were developed, thus allowing fingerprinting studies to be carried out with much smaller quantities of DNA and consequently reducing the initial amount of plant material required, an added benefit when dealing with rare and endangered plants. Several fingerprinting techniques using PCR have been developed. One of the first of these was random amplified polymorphic DNAs (RAPDs), and this has been widely used with cultivated and wild species. However, the technique suffers from lack of reproducibility.

In 1995, AFLP<sup>®</sup> (amplified fragment length polymorphism) was developed by Keygene Inc. (Van *et al.* 1995) and is the most sensitive fingerprinting technique currently available suitable for use with rare and endangered taxa. The technique has several advantages over other currently used fingerprinting methods:

1. It is fast (the technique has been automated)
2. It requires relatively small quantities of DNA, thus making it suitable for work with rare species
3. It provides 10-100 times more markers and is thus more sensitive than some other fingerprinting techniques (e.g. RAPDs)
4. It is highly reproducible

Developed for use with crop plants, this technique has been used in the study of a number of rare and endangered taxa from the temperate regions, including *Astragalus cretensis* (Travis *et al.* 1994), *Orchis alba* (Qamaruz-Zaman *et al.* 1998b), *Populus euphratica* (Fay *et al.* 1999a) and *Physalis* spp. from St. Helena and Tristan da Cunha (Richardson 1999). However, there are relatively few examples of its use with tropical taxa e.g. *Alseodermis* spp. from Peru and Brazil (Hsu *et al.* 1999) and *Physalis* *sicula* from Mauritius and Réunion (Richardson 1999). Here we illustrate the use of AFLPs in the investigation of genetic diversity in two endemic trees from the Seychelles, *Medusagynis oppositifolia* Baker and *Schoenaria ovata* (E.P.Wright) Kunt. This paper is based on two unpublished conservation genetic reports (Fay & Beltran 1999, Fay *et al.* 1999b).

*Medusagynis oppositifolia* is the sole species in the family Medusagynaceae. An endemic to the Seychelles, it is only found on the island of Mahé, where it is known as the jelly fish tree or boen méduse. The botanical and common names refer to the gynoecium which resembles a gorgon's head or the umbrella shaped larval stage of a jellyfish due to the pres-

axis of up to 25 stalked capitate segments. The unusual mode of dehiscence of the valves of the septoid capsule from the base results in a structure at maturity that resembles the ribs of an umbrella. This species was assumed extinct from 1903 until its rediscovery in 1970 as an umbrella. This species was assumed extinct from 1903 until its rediscovery in 1970 as an umbrella. This species was assumed extinct from 1903 until its rediscovery in 1970 as an umbrella. (Robertson *et al.* 1989). The family is monotypic, and its affinities have been obscure.

Originally described by Baker (1877) as a member of Ternstroemiaceae, *M. oppositifolia* was judged to be the sole member of a separate family by Engler & Gilg (1924). A fuller account of Medusagynaceae was published by Engler & Melchior (1935), and the family has been recognised in all subsequent systems of classification (Dickson 1990a). Affinities have been suggested to, among others, Caryocaraceae, Chamiaceae, Eucryphiaceae, Ochnaceae, Paracryphiaceae and Quamocoeae (Robertson *et al.* 1989, Dickson 1990a, b). Molecular studies carried out at Kew (Fay & Chase 1994, Fay *et al.* 1997) have shown that Medusagynaceae is most closely related to Ochnaceae and Quamocoeae. The molecular results indicate that *M. oppositifolia* is a relict palaeoendemic, and it should be given high priority conservation (Vase-Wright *et al.* 1991).

The present habitats occupied by this species indicate that it originally flourished in exposed areas prone to drought. There has been no recent natural regeneration from seed, all plants apparently being a single age (Lucas & Syngé 1978, Gerlach 1997, Wise 1998). Propagation of the species is difficult, and although it has been achieved from seed at Nancy and in tissue cultures derived from seed at Kew, it has thus far not proved possible to generate large numbers of plants *ex situ* (Wilkinson & Stanforth, pers. comm.). Given these problems, *M. oppositifolia* is in severe danger of extinction and has an IUCN category of Critically Endangered (CR, Gerlach, 1997).

As part of the Threatened Plants Appeal organised by the Friends of Kew, we extended our studies of this enigmatic species. It is only known in cultivation from three collections, one at Kew, donated by Whitehead in 1953, and two at Nancy, donated by Friedman in 1983 and 1984. However, it was unclear whether these collections are distinct from the remaining trees on Mahé, and consequently how significant they might be in the conservation of *M. oppositifolia*. To address the questions relating to the origin and distinctness of the cultivated plants and the level of genetic variation existing in this species we carried out genetic fingerprinting studies on cultivated material from Kew and Nancy and samples from the wild populations.

*Rothmannia ornata* (Rubiaceae) is the only species of the genus found in the Seychelles, all others being from southern Africa. Now found only on Anse Island, the most northern of the granitic islands in the Seychelles archipelago, it is thought to have occurred previously on Mahé, Praslin, Silhouette and Felicité. It is known as Wright's gardenia or boss cotton. There are currently approximately 1200 surviving trees (Gerlach 1997, Wise 1998).

Anse Island is 72ha in area, 1.6x0.4 km, and the majority of the *R. ornata* trees grow in shallow soils on granite on the upper slope of a wooded hill that runs east-west along the length of the island. The dominant tree species in the woodland is *Pisonia grandis* Vahl ex Guillaumin (Nyctaginaceae), and *Ficus moultonii* Baker, *F. reflexa* Thunb. (Moraceae) and *Euphorbia pycnantha* Lam. (Euphorbiaceae) are also frequent (Cadbury, pers. comm.). Although locally frequent *R. ornata* is categorised as vulnerable with IUCN ratings of VU (A1d and D) due to the decline in numbers in recent years and the small distribution area (Gerlach 1997).

The Nature Preservation Trust of Seychelles and the Royal Society for Nature Conservation (which owns and manages Aride) approached Kew to ask if we would be able to undertake a genetic fingerprinting project on *R. arnosae* to allow the production of an informed management plan for this species.

## Materials and Methods

### Plant materials

Franke Fleischer-Doyle co-ordinated the collection of plant material from wild plants of *M. oppositifolia* on Mahé. Cultivated material from the Conservatoire et Jardins Botaniques de Nancy, France (provided by the Curator, Romano Pierrel) and from RBG Kew was also included. The samples in this study are listed in Table 1. The collection of leaf material from wild plants of *R. arnosae* on Aride was carried out by Mike Betts, James Cadbury and Elaine Harper. The samples in this study are listed in Table 2. Map numbers refer to localities shown on Fig. 1. Each tree is tagged and these numbers and the DNA bank accession numbers are also given in Table 2. All samples were of leaf material dried in silica gel following the technique of Chase & Hills (1991), except that of *M. oppositifolia* from Kew, which was fresh material from tissue culture. DNAs were extracted using a modified DCTAB (cetyltrimethyl-ammonium bromide) procedure (Doyle & Doyle 1987) followed by purification on caesium chloride/ethidium bromide gradients (1.55 g/ml density) using standard techniques.

### Genetic Fingerprinting

AFLPs were produced following the AFLP Plant Mapping Protocol of PE Applied Biosystems Inc. (1996). Two primer combinations were used with *M. oppositifolia* and three with *R. arnosae*. The fragments were separated on acrylamide gels using an Applied Biosystems Automated Sequencer. Only amplified fragments with sizes ranging from 50-500 base pairs were included in the analysis as bands outside this size range cannot be accurately sized. Gel analysis was carried out with GeneScan 3.1 and Genotyper 2.0 (PE Applied Biosystems Inc.). The bands were scored as either present (1) or absent (0) for all individuals, resulting in a binary matrix which was analysed using the UPGMA (Unweighted Pair-Group Method using Arithmetic Averages) method of genetic distance analysis and by principle coordinates analysis (PCOA).

Table 1. Samples of *M. oppositifolia* used in this study

Origin	Field Notes/Accession	No. plants	Origin	Field Notes/Accession	No. plants
Mahé (wild)	Mt. Service	4	Nancy (cultivated)	833163	1
	Mt. Sable	1		903519A	1
	Copoba	1		903519A	1
Kew (cultivated)	M50C 670	1			

Table 2. Samples of *R. arnosae* used in this study

Map no.	1	2	3	4	5	6	7	8	9	10
Tree tag no.	1001	1011	1102	1113	1114	1115	1117	1118	1119	1120
Kew DNA Bank no.	6602	6603	6604	6605	6606	6607	6608	6609	6610	6611
Map no.	11	12	13	14	15	16	17	18	19	20
Tree tag no.	1101	1102	1124	1125	1126	1127	1128	9528	9529	1129
Kew DNA Bank no.	6602	6603	6604	6605	6606	6607	6608	6609	6610	6611

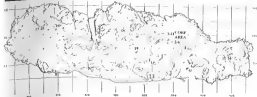


Fig. 1. Map of Arde Island showing locations of the trees sampled

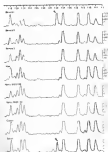


Fig. 2. Specimen traces for samples of *Medusagone oppositifolia*, showing a general high degree of similarity. An example of a polymorphic band, shared by individuals Berman 1 and Sjödin, is indicated by arrows in the top and bottom traces. Numbers at the top of the figure indicate the sizes of the fragments in base pairs and numbers at the side indicate the strength of the peaks in arbitrary units of fluorescence.



## Results & Discussion

### *Alechinagyne oppositifolia*

In total, 119 bands were scored, 16 of which were polymorphic. The level of sampling of wild plants in this study was low as a result of the difficulty in reaching some of the locations where the remaining trees grow, but the level of variability in the individuals tested was also low, as might be expected given the recent history of this species. The maximum genetic distance within the samples of *M. oppositifolia* was approximately 6.8%, and there was little clear geographical structure in the results for *M. oppositifolia*, either in UPGMA or PCOA. Of the plants sampled, that from Mt. Sablet was genetically the most distinct. Cultivated plants from both gardens had similar genotypes to plants from Bartsia, although one plant from Nancy appeared to be slightly more distinct than the others in PCOA. Examples of the fingerprint traces are shown in Fig. 2. The cluster diagram derived from the UPGMA analysis is shown in Fig. 3 and the plot of the first two axes from PCOA (accounting for 31.4 and 19.1% of the variation, respectively) is shown in Fig. 4.

Plants at Nancy and Kew should be conserved as a valuable *ex situ* resource in the conservation of this species, and they should be maintained in the collections at both gardens. However, these cultivated plants do not represent lineages no longer found on Mahi, and there thus appears to be no benefit to be gained from repatriation of material in terms of widening the genetic base of this species in the wild.

If it is possible to obtain further samples of leaves from other wild plants, these should be included in an expanded analysis. In the meantime, any seeds produced by the cultivated plants should be stored in a seed bank under controlled conditions. Consideration should also be given to storing seeds from wild plants to ensure that the genetic variability found in *M. oppositifolia* is maintained.



Fig. 3. UPGMA cluster diagram of *Alechinagyne oppositifolia* individuals based on AFLPs

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In all, 122 beads were scored, of which 14 were polymorphic. In the UPGMA analysis, the maximum genetic distance within the samples of *R. ornata* was approximately 6%, with two individuals (tag nos 1118 and 1127) falling outside the main cluster. One of these, 1118, is an individual from the core area, whereas the other is an isolated individual from the west of the island (see Fig. 1). In the main cluster, genetic variability was low, with most the genetic distances being <2%. Within this cluster there were four smaller clusters, comprising of seven, four, two and two individuals, within which the individuals were not distinguishable from each other as they showed identical AFLP profiles. The remaining three individuals also fell within the main cluster but differed from the other individuals by at least one band. Examples of the fingerprint traces are shown in Fig. 5. The cluster diagram derived from the UPGMA analysis is shown in Fig. 6 and the plot of the first two axes (accounting for 30.6 and 9.1% of the variation, respectively) in the PCOA is shown in Fig. 7. There was no clear geographical structure in the variation with similar genotypes occurring in different populations.

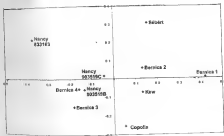


Fig. 4. Plot of the first and second axes from a PCO analysis of *Medicagynae opportunistae*.

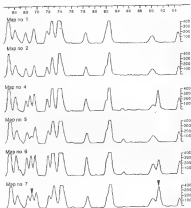


Fig. 5. Spectrum traces for samples of *Rothemannia aranea* from Ando Island, showing the general high degree of similarity. Polymorphic bands are indicated by arrows in the bottom trace. Numbers at the top of the figure indicate the sizes of the fragments in base pairs and numbers at the side indicate the strength of the peaks in arbitrary units of fluorescence.

Proving that individuals are genetically identical is considerably more difficult than proving them to be distinct, and the individuals that are not distinguishable from each other in that analysis are not necessarily genetically identical. However, the AFLP traces for these individuals bear the same degree of similarity to each other as those for material of known clonal origin (e.g. with *Cosmos atrorubescens* (Hook.) Stapf (Asteraceae), Fay unpublished data) and Wilkinson 2000) and AFLPs have been used as supporting evidence for the clonal origin of plants in populations of *Populus euphratica* Oliver (Salicaceae, Fay *et al.* 1999) and *Salix* spp. (Salicaceae, Beermann *et al.* 1997).

Given the low level of genetic variation, for the continued survival of *R. arvensis* it is clear that every effort should be made to maintain the current level of genetic diversity, and that relative genetic outliers such as 1118 and 1127 are likely to be important in this process. More detailed sampling would be required to ascertain whether these are representative of other genetic clusters not otherwise represented in this sample or whether they are truly distinct genotypes. This study provides the background for a project with increased sampling.

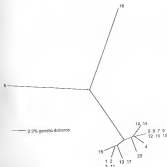


Fig. 6. UPGMA cluster diagram of *Rostkovia arvensis* individuals from Ande Island based on AFLPs. Numbers refer to the locations shown on Fig. 1.

Given the lack of geographical structure, it is not possible to designate populations of *R. cretaea* on Ande that are more important genetically than others. The small size of the island probably means that pollination is still occurring between the remaining populations and that there is therefore gene flow between them. The genetic data presented here support this hypothesis. Rather than conserving individual genotypes, as the distinct genotypes are distributed across the different populations on the island, it appears to be more important to control factors that lead to the population decline in this species.

In conclusion, genotoe fingerprinting using AFLPs has been shown here to be an appropriate tool for the assessment of levels of genetic variation in the remaining populations of two endemic species from the Seychelles. The data collected have been used to inform the management of these species for their conservation and will, we hope, contribute to the continued survival and wellbeing of these species.

### Acknowledgements

We gratefully acknowledge the financial support of the Friends of Kew through the Threatened Plants Appeal. Without their support, much of the work presented here would not have been possible. The Ministry of the Environment, Seychelles gave permission for the samples to be collected. We also wish to thank Franke Floricher-Dogley, Mike Betts, James Cadbury and Elaine Harper for organising the collection of the plant material from the wild, Romanus Perrot (Carnot, Conservatoire et Jardins Botaniques de Nancy) for providing samples from the cultivated material held at Nancy, Tim Wilkinson and Martin Stanforth who maintain the plants of *M. oppositifolia* at Kew that were used in this study, and Mark Chase for his ongoing support of the Conservation Genetics Programme.

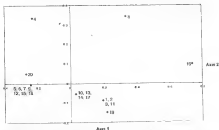


Fig. 7. Plot of the first and second axes from a PCO analysis of *Anethum cretaea* individuals from Ande Island. Numbers refer to the locations shown on Fig. 1.

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# Conservation status and management of Wright's gardenia *Rothmannia ansonae*

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**Abstract:** The Seychelles endemic tree *Rothmannia ansonae* (Palafoxia) was historically widespread in the granitic islands but since the early 1900s has been restricted to Ande island. On Ande it has been monitored since 1966; the population is currently believed to be stable at just under 1000 mature plants. The population is secure inside Special Reserve and conservation management aims to establish further wild populations on other islands.

**Keywords:** Ande island, Seychelles, tree

Wright's gardenia, *Rothmannia ansonae* (Wright) Keay, is a small tree endemic to the granitic islands of Seychelles. Historically, it was widespread in the islands but has been restricted to Ande island since the early 20<sup>th</sup> century. It has also been recorded on Mahé (1871, 1874 and 1899, Summerhayes 1931), Silhouette (1905, Summerhayes 1931), Prédin (1871, Summerhayes 1931) and has also been cited without further details from Felicite (Friedmann 1994). The population in the Ande Island Special Reserve is largely associated with open glades and edge habitats and it may have been a relatively uncommon constituent of lowland and coastal forests on all the islands.

Its decline on most islands can be attributed to clearance of the lowland forests, with Mahé and Prédin being cleared in the 19<sup>th</sup>-20<sup>th</sup> centuries, Felicite and much of Silhouette shortly after 1905 (Gerlach 1997). The lowland forests on Ande were maintained, although extensively modified, to encourage setting of sooty terns (*Sterna fuscata* Linnæus, 1766). The hill woodland dominated by *Placenta grandis*, *Ficus lutea*, *F. reflexa* and *Euphorbia pectinata* was coppiced while the plateau was converted to coconut plantation. *R. ansonae* appears to have survived in the coppiced hill woodland and may have benefited from the open aspect of such managed woodland. Although the woodland has regenerated to a semi-natural state since coppicing ceased in 1984-7 (Carty & Carty 1996) a notable proportion of the coppiced trees are still present (in 1987-8 37% of the *R. ansonae* showed signs of coppicing, Bullock 1989).



Fig 1. *Rothmannia ansonae*

Phytoma 8(2000), 13-27



Other historical threats have been suggested to include attack by stem mealy bugs (*Coccordex*) which has been suggested to have caused the decline in the species, while a scarcity of such parasites has been suggested to have allowed its survival on Aride (Friedmann 1994). The significance of parasitism has been disputed (Gerlach 1997) and this is an unlikely cause of decline as mealy bugs and scale insects are also abundant on Aride. *R. arnos* has not been observed to be exceptionally badly affected by mealy bugs. In addition mice (*Neotoma* Linnaeus, 1758) have been recorded eating seedlings and seeds (Bullock 1989) but these were nursery specimens and field data suggest that few seeds are consumed by mice (9% of mice from hull woodland in 1999 may have consumed single *R. arnos* seeds at a time when fruit was abundant, the figure for all habitats is 2%, Bowler & Hunter 2000).

As Aride retains the last wild *R. arnos* the conservation of this population is of great importance and has been a high priority in monitoring and management work on the island. The current conservation status and ecological information on this species is summarised below.

### Status on Aride

The population of *R. arnos* on Aride has been monitored since 1983. The first survey used a Point Centre Quadrated method for trees over 1.75m in height (Baum 1985), subsequent surveys have been whole-island surveys, aiming to count all individuals. Comparisons of the census data may not be reliable due to the different methods used and the highly clumped distribution of trees imposing difficulties on evaluating reliable error limits (Martin 1997), however, the data are compared in Table 1.

The large decrease between 1983 and 1987 can be ascribed to differences in survey methods (Martin 1997). Decreases since 1987 have been suggested to be significant and a cause for great concern (Carty & Carty 1996, Gerlach 1997). However, the reliability of the data have been questioned, the 18.3% decline reported by Carty & Carty (1996) (corrected to 16.9% in Martin 1998) is not statistically significant (Martin 1993). The accuracy of the 1995 survey is further questioned by the apparent increase in 1997-9. Over the 12 years of whole-island surveys the population of adult trees has declined by 12.6% (1.05% per year) although since 1989 there has been a decline of only 3.8%. On this basis the population appears to be stable at approximately 1000 mature trees. All 987 trees over 1.5m in height now bear a uniquely inscribed aluminium tag attached by heavy-duty wire to allow identification of individual trees in subsequent surveys: a valuable monitoring and management tool.

*R. arnos* was considered to be vulnerable in 1997 (Gerlach 1997, Oldfield *et al* 1998, Walter & Callan 1998) on the basis of its restricted range and the suggested population decline. As the revised data indicate a stable population of 1000 individuals and the species is widespread across Aride's 73ha, the species may appear to be under less threat than was

**Table 1.** *Roystonea arnos* census data

Year	Number of mature trees	Source
1983	2718 (1914-3217 95% confidence limits)	Baum 1985
1987	1028	Byssell 1987
1989	1018	Bullock 1989
1995	938 (corrected to 979, Shaw & Upton 2000)	Carty & Carty 1996
1997/8	804 (corrected to 982, Shaw & Upton 2000)	Hill 1999
1998/9	987	Shaw & Upton 2000

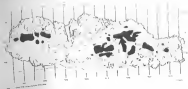


Fig. 2 Distribution of *R. annua* on Ande

believed earlier. However, application of the IUCN Red List Criteria (IUCN 1994) still classifies *R. annua* as vulnerable (Vu D1.4.2 - less than 1000 mature individuals and population restricted in area [ $<100\text{km}^2$ ] and number of locations [ $<5$ ]).

#### Ecology

The heavily scented flowers may be produced in all months, particularly after heavy rain. There is a peak of mass flowerings in October-January. This relates to flowers opening 6-13 days after rain (mean 9.8) (Bullock 1989). It has been suggested that the flowers may be self-fertile (Castle & Miles 1991), however, the flowers are male or female by selective abortion by different individuals (Friedman 1994), the female flowers are slightly more spotted. Studies of flower types have recorded that 17.7% were white, 41.9% sparsely spotted, 40.3% heavily spotted ( $N=62$ ) (Bullock 1989). White and sparsely spotted flowers are assumed to be predominantly male, giving a suggested male biased sex ratio of 1:48:1.

Fruct is set in only 3% of flowers (Castle & Miles 1991). The majority of trees that each year in January-February 1996 76.4% of trees were fruiting. Relatively few fruits produce seedlings and of the trees recorded fruiting in 1996 32.8% had seedlings under the canopy, and of these only 9.7% had seedlings growing to over 25cm (Stoneman 1996). This appears to be principally due to smothering by weeds, in particular *Aystonia* sp. In favourable situations seedling survival is high and 14 month survival has been calculated at 39.2% (Bullock 1989).

The majority of trees continue to grow and height increases have been recorded since 1988 with mean annual growth of 0.2m (1988-96, data in Castle & Miles 1991, Stoneman 1996). Mean height is currently 7.7m (in 1996, Stoneman 1996). These height measurements are estimated and subject to recorded error, however, directly measured diameters at breast height have also increased in the same time period. During 1988-92 diameter increased by a mean of 0.52cm (Castle & Miles 1991), in 1992-6 98.4% increased their diameter, with an increment of 1.53cm (Stoneman 1996). These give an average annual increment of 0.31cm.

Conversely, a significant proportion of the population has decreased in canopy size.

The extent of canopy decrease varies across the island: in 1992-6 declines were more frequent in closed woodland (66.6% of trees) than in edge/open habitats (34.6%) (Stonerian 1996). During the same time there was an increase in shading by *Pisonia grandis* and *Ficus religiosa*, this effect will be much more pronounced in closed woodland than in more open areas (Stonerian 1996). It should be noted that canopy decreases were much smaller than increases.

There are few direct observations of pollination or seed dispersal. Flowers are visited by the Seychelles sunbird (*Nectarinia dussumieri* (Hartlaub, 1860)), the carpenter bee *Megachile morio* (Perez) *seychellensis* and the leaf-cutter bee *Megachile s. seychellensis* Cameron, 1907. Dispersal agents may be speculated to include fruit bats (*Pteropus seychellensis* Milne Edwards, 1888) and giant tortoises (*Dipsochelys* spp.). Small numbers of fruit bats are present on Anse but are not permanent residents, these appear to be attracted to the island by the large numbers of fig trees, consequently the bats may overlook the *R. axon* fruit, no bats have been seen feeding on *R. axon*. Dispersal by tortoises may have been significant in the past but native giant tortoises are extinct on Anse and the small number of introduced Aldabra giant tortoises (*D. aldabrensis* (Gray, 1835)) were removed from the island in the 1970s. Currently dispersal appears to be very limited, seedlings are most abundant under parent trees and saplings and mature trees show a distinctly clumped distribution.

### Management

Seedlings on Anse are extensively overshaded, with clearance of ground cover seedling growth has been recorded as 5cm per month (Carty & Carty 1996). Overshading has been countered by selected removal of *dryasias* sp. and *Pisonia grandis* from hill trees (Bowler & Hunter 1999) although this is not maintained as a permanent management technique but rather a means of providing temporary protection for selected trees. Planting on Anse has aimed at spreading the species into unoccupied areas on the plateau, although survival has been low (Bowler & Hunter 1999), there is currently no interventioned management for *R. axon* on Anse due to its apparent stability.

*R. axon* has been planted on other islands, initially as small numbers for ornamental purposes on Mahé. Significant introductions to other islands started in 1994 and subsequently on a semi-annual basis (Mahé 1995-99 - Carty & Carty 1996, Bets 1996, Bowler & Hunter 2000), Cousin (1994-5 - Carty & Herzig 1995, Carty & Carty 1996), Cousine (1994-6 - Carty & Herzig 1995, Bets 1996), Curieuse (1995 - Carty & Carty 1996), Fradin (1994-7 - Carty & Herzig 1995, Carty & Carty 1996, Bets 1997), Fregate (1996 - Bets 1996 & 1997) and Sefouette (2000). A variety of techniques have been used, from the export of seedlings, cleared seeds and whole fruit. Cleared seeds and fresh fruit have proved to be most effective (80% germination rate [N=500] - F. Dogley pers. comm.) and adaptable but germination rates from old fruits have been very poor (0-6%, Bowler & Hunter 2000).

The majority of seedlings transferred to Cousin, Cousine, Curieuse and Fradin died, those maintained at the Botanical Gardens on Mahé have been successfully established and trees planted in 1996 flowered in 1997 (Bets 1997), with fruiting in 1999 (Bowler & Hunter 2000).

### Prospects

In order to determine whether special conservation measures were needed to maintain the genetic diversity of *R. amare* a genetic study was initiated (Pay *et al.* 2000). This found very restricted genetic variation (maximum of 6%) with no geographical pattern within the Aride population. 2 of the 20 individuals sampled were categorised as genetic outliers and these are to be included in future distribution of seed to other islands to ensure that as much genetic diversity as possible is established in new populations.

The available data suggest that *R. amare* is stable on Aride and the population is expected to remain at just under 1000 individuals without active management. Accordingly there are no plans to increase the numbers or extend the distribution on Aride unless future monitoring data provide evidence of further decline. The most productive approach for improving the conservation prospects for *R. amare* will be to re-establish populations on other islands. A number of trees have been established on Mahé and 25 seedlings were planted by the Division of Environment at Mace aux Cochons. Growth of these seedlings has been variable with significant die back during dry weather. Attempts to establish the species on other islands have had only limited success and need to be extended. At present, the best prospects lie with the extensive habitat restoration plans for Fregate and Silhouette. Seedlings have been established in a nursery on Fregate and the first seeds were sent to Silhouette in April 2000.

Due to the restricted land area of the granite islands of Seychelles *R. amare* will always be categorised as vulnerable by nature of a restricted range (IUCN Red List Criterion V<sub>1</sub>, D<sub>2</sub>). Other threats to its survival can be reduced by increasing the number of mature individuals in the wild to over 1000 and establishing at least 4 more discrete populations. With maturity in 2-3 years there is a possibility that wild populations may be considered to be established on Fregate and Silhouette by 2003. It should also be possible to establish viable populations on Cousin, Cousine, Curieuse and North islands as part of existing or planned habitat management on those islands.

### Acknowledgements

The authors wish to thank Rodney Fanchette and Gerald Monthy for collecting seed from Aride and Frauke Fleischer-Dogley and staff at the Division of Environment for supplying information on their propagation programme.

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# The feeding ecology of greater frigatebirds *Fregata minor* and lesser frigatebirds *F. ariel* on Aride island

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**Abstract:** The behaviour of frigatebirds on Aride island is described. Kleptoparasitic attacks were made by both greater and lesser frigatebirds. For lesser frigatebirds most attacks were made by males, for greater frigatebirds most attacks were by juveniles. Almost half of all attacks were on wedge-tailed shearwaters, a total of 18 bird species were observed to be attacked. 10 cases of hyper-kleptoparasitism were observed by common noddies.

**Keywords:** aggression, kleptoparasitism, *Stercorarius*

There are large numbers of roosting frigatebirds *Fregata* spp. found on Aride island, almost 4000 were recorded in November 1996 and 1999, with a maximum of 4555 in 1998 (Borch 1997, Bassler & Hunter 1999). Although they have never attempted to nest there (the main regional nesting ground is Aldabra), their stunning acrobatics and kleptoparasitic hunting methods are a dramatic sight around Aride. Two species are present, greater frigatebirds *Fregata minor* (Gmelin, 1789) and lesser frigatebirds *F. ariel* (Gray, 1832).

Frigatebirds are notorious for their airborne piracy, stimulating early observers to conclude that it was their sole method of feeding. In fact, a small proportion of the food supply in any frigatebird population stems from this source, although some individuals may subsist mostly by piracy (Nelson undated). Conflicting reports exist about the nature, extent and success of piracy and, although studies have been carried out on a number of island colonies (the Galapagos, Aldabra and Christmas Island), little is known about the colony on Aride.

Frigatebirds have a highly-specialised feeding technique - snatching flying fish and squid from the surface, for which their long, thin bills are ideally suited, supplemented by kleptoparasitism on the abundant bird species, conducted mainly in impoverished seas. Other attacks and feeding behaviour, such as snatching offal and carrion from the sea, killing newly fledged young of small seabirds such as shearwaters and toying with incapacitated birds on the surface of the water, are considered to be unimportant opportunistic events (Nelson undated).

The aim of this study was to observe the feeding behaviour of the frigatebirds population on Aride island, and their kleptoparasitic behaviour in particular. From observations of feeding methods the effects of kleptoparasitic attacks on the nesting seabird population was to be determined.

## Methods

Initially, random observations were made at various points around the island, to determine the ideal location from which to observe the frigatebirds feeding. Due to the high incidence of nesting seabirds across the island during the study, access was restricted and

optimum locations were limited. Five locations were eventually chosen: 'Richard's Rock' (RR) on the north-east end of the island, along rocky cliff promontory over-looking Ti L'Anse (GR 52773457), 'Cote Desree', at the east end of the south beach (GR 51433428), 'La Pointe L'Anse', at the west end of the south beach (GR 51753434), the 'Western Beach' (WB), a rocky promontory overlooking a small bay at the west end of the island (GR 51323474), and the 'North-West Rocks' (NWR), a large flat granite slab on the north-west shore of the island, approximately 300m west around the coastline from the base of the 'Gros La Tete Lookout' (GR 51403480).

Observation days in June-August 1999 were divided into three watch periods: morning (07 00-10 00hrs), midday (10 00-14 00hrs) and afternoon/evening (14 00-18 00hrs). Observations were made randomly at the different locations. Frigatebirds were most frequently and more reliably observed feeding along the north/north-west coasts (close to their established roost sites).

Attacks on other birds were watched through 10X binoculars. Where possible the observations were categorised according to species (lesser/greater), age (juvenile/adult), the number of individuals involved and whether any other species of seabird joined in the attack. Species identifications were uncertain during periods of low light, poor weather conditions and when attacks occurred far from the shore (beyond the effective range of the binoculars). In such situations a record of the attack, its duration, number of birds involved and success was made.

Recording of an attack started from the moment a frigatebird went into an attacking stoop (wings folded, head strung forwards, dropping vertically after the victim at high speed). An attack was considered unsuccessful if:

- i) the victim escaped unharmed using evasive manoeuvres
- ii) the frigatebird broke off the attack
- iii) the victim managed to reach the safety of dry land

An attack was considered successful if:

- i) the victim regurgitated its catch into the sea and the pursuing frigatebird caught the 'prize' from the surface (categorised as 'successful regurgitation')
- ii) the victim was caught by the wings and seriously/mortally injured (considered to be 'killed') whilst also dropping its catch
- iii) a victim when harassed in the air dropped its catch, the frigatebird would then attempt to catch the 'prize' in mid-air

During the attack other behavioural details were noted, such as the flight pattern of an attacking group (a rolling or massed attack), whether it was a co-ordinated pair attack (male and female), the flight pattern (rolling or direct) and whether the frigatebird flew into the sea. The behaviour of other seabirds and their influences on the attack result were also noted.

**Results** Over 27 days, 59 hours of observations were collected on a total of 687 birds (frigatebirds and other seabirds) involved in 254 attacks on 287 seabirds. On 6 days no attacks were seen (2 of these being days of heavy rain), possibly due to low numbers of feeding seabirds. A total of 3,943 seconds of attacking behaviour was observed, each attack taking 15.5 seconds on average (sd = 17.68, range = 2-150).

The results are summarised in Table 1-2. 38.6% (n=96) of attacks were successful (regurgitation seen), of which 29.5% (n=29) were confirmed 'kills' through wing-biting or 'mobbing' of the victim on the surface. On one occasion, a large group of frigatebirds attacked a shearwater 'raft' causing mayhem. Of the total confirmed attack attempts 61.4% were unsuccessful, of these only 0.26% of victims escaped to dry land.

On 10 occasions (3.93%) a common noddy *Anous stolidus* (Linnaeus, 1758) was present to steal the discharged fish from a harassed victim, before the frigate had a chance to circle round to collect their prize. Only on two other occasions were other seabird species seen to join in with the attack (a lesser noddy, *Anous leucurus* Temminck, 1815 and a wedge-tailed shearwater *Puffinus pacificus* Gmelin, 1789. On one occasion, and a sooty tern *Sterna fuscata* Linnaeus, 1766 on the other).

7.68% (n=18) of attacks were made in mid-air with the frigatebird hitting the victim whilst on the wing, usually carrying food in the beak. These attacks were mainly on white-tailed tropicbirds (*Phaethon lepturus* Lacépède & DuRoi, 1802) and fairy terns (*Gygis alba* Sparrk, 1786). The two instances in which greater frigatebirds were recorded chasing lesser frigatebirds were conspicuous as it was after the lessers had scooped up and were carrying food of their own. There were many other cases of the two species chasing each other but none of these were categorised as attacks during this study.

A number of times (1.2%, n=3) pairs of lesser frigatebirds were observed harrying together. For the purposes of this study this was called a 'paired rolling attack'. Either of the pair would execute a stooping attack on the victim, chasing it low over the surface of the sea for a number of seconds, whilst the second bird would climb steeply and at an optimum moment dive down at great speed, usually hitting the victim with considerable force. The second bird would continue the low-level chase while the first proceeded to climb and repeat the attack, integrating a rolling pattern. This usually continued until the victim regurgitated.

**Table 1.** Identity of aggressors

N=287	% of attacks	% males	% females	% juveniles
Lesser frigate	40.5	52.2	13.4	35.1
Greater frigate	46.3	8.3	12.4	79.0
Common noddy	1.7			
Sooty tern	0.3			
unidentified	1.0			

**Table 2.** Identity of victims

N=287	% of victims	species	% of victims
Wedge-tailed shearwater	48.1	Common noddy	6.6
Lesser noddy	12.7	Andean's shearwater	3.8
White-tailed tropicbird	13.3	Lesser frigate	0.7
Sooty tern	13.5	Greater frigate	0.7
Fairy tern	7.3	Rosette tern	0.3



was incapacitated on the water, escaped or was killed.

6 instances (2.36%) were recorded of 'pack rolling attacks'. This was a similar hunting pattern to the one described above, but involving greater number of birds, sometimes up to 30 attacking a single victim. These hunting patterns were in marked contrast to the apparent frenzy which ensued, if an individual started an attack in the presence of significant number of other hunting birds. It is worth mentioning that after one of these disorders a juvenile greater frigate was seen to fly into the sea. After 5 seconds of considerable effort, it managed to become airborne again after avoiding becoming totally waterlogged.

## Discussion

During the study the numbers of frigatebirds of both species increased from 699 to 1340 individuals, the highest counts since records began in 1987 (Bowler & Hunter 2000). The high population of birds accounts for the large numbers of birds seen feeding off the north of the island early in the 'season', this in turn accounts for the high sample numbers of attacks observed during the study.

Differentiation between species, sex and sexual maturity was extremely difficult during the fall population counts carried out from the boat, although the high proportions of juveniles of both species and of lesser frigate males observed during the attacks may give some indication as to the proportions present at the time. Lesser frigates appear to be over-represented in attacks (forming only 1.2% of the population in 1990 (Castle & Mileto 1990). Of the greater frigate population juveniles appear to attack more than expected (forming only 27% of the population - Castle & Mileto 1990). These 1990 data are supported by more recent observations (lesser frigates forming 4-18% of the population in 1999 - (Bowler & Hunter pers. comm.)). It is speculation whether this influences the number of attacks and other behaviour of the frigatebirds at the time, but the high incidence of juveniles making attacks could suggest that Arde is a proving ground for the hunting skills of the birds. Indeed, juveniles were often observed apparently 'playing' with their victims long after they had regurgitated their catch or harassing them on the surface of the water for no apparent reason. It has been mentioned that low fish stocks in the ocean have led to bird species resorting to desperate measures to obtain food, evidence of which exists in this study, with instances of kleptoparasitism being practised by seemingly non-aggressive species (e.g. common noddies and sooty terns). Could this account for the apparent motiveless aggression of the frigatebirds?

Nelson (undated) suggested that this behaviour only occurs in impoverished seas, and that the high number of juveniles apparently practising their hunting techniques could be accounted for by development of their specialised feeding ecology. "Impoverished pelagic habitat and/or specialised feeding techniques lead to slow growth of young and an extended post fledging period to enable the acquisition of specialised feeding techniques". He also suggests that the practice of stealing objects in the air as exhibited by many of the young is a simple form of piracy practised while still immature, but does not explain the conspicuously vindictive behaviour as shown by the high proportions of juveniles frigatebirds (of both species) around Arde.

To substantiate this claim with regard to the Arde population, data on the status of fish stocks in the frigatebird breeding ground at Aldabra would need to be acquired and

comparison made with the status of fish stocks around Aride, to deduce why this year, such large numbers of birds have migrated north so early and exhibited this kind of behaviour.

The principal victims of the frigatebirds around Aride were wedge-tailed shearwaters (in contrast to Bullock's (1989) claim that the main prey are tropicbirds, common noddies and lesser noddies), although from the study it is clear that almost any bird may be chased by frigatebirds, including each other. On Aldabra the principal victims are red-footed boobies (Lunniss, 1966), whose distribution is closely matched by that of greater frigatebirds (Nelson undated), although this obviously is not the case around Aride. Maybe in this instance it is just a case of the largest and most successful number of feeding seabirds around the time. The data in Table 2 indicate that the frigatebirds are not simply attacking the most abundant species (comparing the rank of victim identity and seabird census data [Bowler & Hunter 1986] gives Spearman's  $r = 0.367$ ,  $P_2 > 0.2$ ).

According to Nelson (undated) adults of both species chase, but unequally, with greater frigate males chasing more often than females (Galapagos), greater females chasing more than males (54/2) (Christmas island) and females chasing more than males for both species on Aldabra. Around Aride however, lesser frigate males chased more than females, with similar numbers of both sexes of greater frigates carrying out airborne piracy. Regional variations in food source and sex ratios within the population may influence observations.

Most of the chases around Aride occurred in the late afternoon, when many seabirds were returning from the sea with full crops. It is clear that frigatebirds do not chase indiscriminately but choose their victims carefully. At the time of the study however, it is worth noting that large numbers of nesting seabirds would also be returning from feeding with full crops specifically to feed their nesting young. This, coupled with the constant influx of 'new' frigates migrating from Aldabra, could explain why the number and intensity of attacks increased as the nesting season progressed (and consequently the seabird chicks matured and began demanding more food). Whether this is another factor influencing the protracted nature of many of the attacks around Aride for a large 'prize' is speculation, but on Aldabra Nelson (undated) found that the frigatebirds would often quickly abandon a pursuit of boobies, presumably in response to some undetected cue. If this was the case around Aride, then a correlation must also be drawn between all these factors and the sexual maturity of the frigatebirds, the immature birds showing a tendency to continue chasing (without success) long after old frigates would have abandoned the pursuit.

Despite this eagerness to pursue it is apparent that the success rate of frigatebirds practicing kleptoparasitism in general is relatively low and that in fact most frigatebirds actually get most, if not all their food by snatching flying fish and squid from the surface of the sea. For example diamond (1973) found that in only 18% of the 55 attacks observed did a frigatebird obtain food regurgitated by a booby. Similarly, greater frigates in the Galapagos have a 12% success rate (Nelson undated), although it may be as high as 63% on Christmas island (Schreiber & Ashmole 1970). The 38.5% success rate for Aride is much higher than the Aldabra rate and, although this may be due to the difference in sample sizes, other factors such as lack of natural food availability to stimulate kleptoparasitism and high predator to prey ratio could also influence the result.

At first glance, it appeared that the amount of energy and effort expended during each attack, was vastly disproportionate to the small amount of food gained, although from

continued observation, either the attacker or victim (if it escaped physical damage) seemed relatively fresh even after the more prolonged attacks. Both have adapted to spending long periods of time on the wing, so it is only logical to assume that either could sustain prolonged periods of attacking with relatively little additional expenditure and few detrimental effects on their physiology. Anyway many of the attack periods (early morning or late afternoon) were short-lived, based on the numbers of returning birds laden with food.

Hyper-kleptoparasitism was first observed off Arde in 1999 (J. Bowler pers. comm.) when a common noddy was observed following in the path of an attacking group and continually 'stealing' the stolen food from underneath the kleptoparasitic frigatebirds. Several (10) additional observations of this unusual behaviour by common noddies were observed after this sighting, which suggests that it is more common than one would imagine. Maybe it is another case of hungry species adapting to more desperate measures to obtain food in impoverished seas. If this is the case, then it may be possible that other species would begin to adapt in the near future. Alternatively, it could be another example of opportunistic hunting, as exercised by the frigatebirds themselves.

It does seem curious however, that in 1987, it was suggested that the majority of birds parasitized by frigatebirds were in fact common noddies (Bullock 1989). It is possible therefore that significant adaptive behaviour within such a small population, seems to have occurred even within such a short time (although the observations made in 1987 were not extensive and conclusive) and may be just another example of the unique dynamics that are occurring within the Arde ecosystem.

## Conclusion

From this study it is clear that although piracy on seabirds by the frigatebirds can appear extremely traumatic and vicious at the time, due to the low success rate and opportunistic nature of the attacks, it is unlikely that they are having a significant detrimental effect on the nesting seabird populations of Arde. The fact that many of the perpetrators and the nature of the attacks at the time of the study were juveniles, could suggest that Arde is a training/proving ground for the highly specialised hunting methods required by the frigatebirds.

High numbers of nesting seabirds across the island and the requirement for seabirds to bring in food for their young are significant factors influencing the number and success of attacks at the time. The instances of hyper-kleptoparasitism are significant in that they may either be an indication of poor food levels available in the sea, or an example of specific adaptive behaviour.

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# Kleptoparasitic theridiids spiders of the granitic Seychelles (Araneae, Theridiidae)

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**Abstract:** Seven kleptoparasitic theridiid spiders from the genus *Argyrodes* Simon, 1894 are recorded from the granitic Seychelles islands. The male of *Argyrodes mormonae* Saaristo, 1978 and the female of *Argyrodes pumila* Saaristo, 1978 are described for the first time.

**Key words:** Kleptoparasitic, *Argyrodes*, Theridiidae, Seychelles

## Introduction

Members of the genus *Argyrodes* Simon, 1894 are kleptoparasites living on the webs of other spiders. They are especially common on the large orb-webs and on Seychelles they are mainly found on webs of *Nephila macrura* (Walckenaer, 1841), *Nephilengis cruentata* (Fabricius, 1775), *Cyrtophora citricolor* (Forskell, 1775), and different *Tetragnatha* species. Relationships between kleptoparasite and host vary according to the species. Some of them are harmless guests feeding on very small prey from the host's web while others steal prey from the host. Some species catch their own prey by cutting a small section out of the host's web, replacing it by their own threads. Finally some are araneophagous and prey on their hosts.

*Argyrodes* is a large genus comprising over 120 species found in warm and tropical parts of the world. Although *Argyrodes* indisputably is a monophyletic taxon the general appearance of its members is by no means uniform and it is not possible to give an unambiguous description for the genus. For example the shape of the abdomen varies from more or less globular (Fig. 9) to worm-like (Fig. 8). Also colouration of the abdomen is highly variable. Usually it consists of dark (rusty brown - black) and light (dirty white - yellowish) areas, with silvery shining corpuscles on light areas, these corpuscles may be fused to cover the light area entirely so that abdomen looks like a small silver piece. The colouration is also highly variable within the species. Thus even on the same host's web there may be very dark, blackish or rusty brown specimens or light ones with large silver patches. Most, but not all, males have their cephalic region modified to lobes or horn-like projections bearing specially modified hairs. However, there are certain pronounced differences in the general lay-out of these projections and without doubt these structures are not all homologous. In some species the AMEs and PMEs are situated on a dorsal lobe and below it there is a frontally directed, or less horn-like projection (Figs. 3A-5A). But in some species there is a single horn standing between the AMEs and PMEs (Figs. 6A-7A) or a horn-like swelling below the AMEs (Fig. 9A). Finally, in some species the eye region is only moderately elevated (Fig. 8A). The legs are often long or very long, e.g. in the Seychellian species carapace/abdomen varies between 0.86 and 0.26. All species have a stimulatory organ, on the posterior end of the carapace there is of a pair of oval shaped areas with transverse ridges and on the anterior part of the

abdomen there is a half circle consisting of stiff hairs with elevated bases (Fig. 7C).

The general lay-out of the bulbous of the male palp is very typical (terminology used here is from Saenko 1978 and refers to the left palp). Arising from the right half of the regular locking arm A (laA) winds clock-wise behind the other bulbous structures, ending close to the apex of the cymbium at its right side. On this site, inside the cymbium there is a small hook-like extension (ch) which fits into a small pit in the apex of the locking arm. Inside the circle of the locking arm stands an arm-like terminal apophysis (ta). The apex of the terminal apophysis is usually dilated, bearing often dendrites arranged in various kinds of rows. On the right side of the terminal apophysis lies the embolic complex (ec) which has a bulbous basal part bearing the embolus proper and one or two spine- or arm-like extensions. Close to the embolic complex, behind it or on its right side stands a more or less translucent conductor A (cA). The apex of the conductor is wrapped around the embolus proper. Structurally the male palps can be divided into five main types which can be shortly described according to the shape of the terminal apophysis: (A) terminal apophysis fairly long with triangular apex (Fig. 1A-C), (B) is relatively short, flat and broad with rows of dendrites at its apex (Fig. 1D), (C) is long and narrow, blunt tipped with scattered dendrites at its apex (Fig. 1E), (D) is fairly short, flat and strongly dilated apically (Fig. 1F), and (E) is very weakly developed, transparent (Fig. 1G). The corresponding structural groups can also be found in epigynes: (A) openings of the entrance ducts (oeds) within shallow spiral-like depressions connected to others by a narrow posterior ridge (Fig. 2A-C), (B) oeds inside a small, oval-shaped depression at the anterior end of a trunk-like median elevation of the epigynal area (Fig. 2D), (C), oeds inside an oval-shaped depression close to the epigastric fold (Fig. 2E), oeds on each side of a broad, ridge-like elevation at the posterior end of a median oval-shaped depression (Fig. 2F), and oeds on each side of a nose-like elevation at the corner of the epigynal area. The epigynes of mated females are regularly plugged with reddish brown excrecence which may sometimes be quite massive (Fig. 6C).

The above presented groups of the secondary genital organs have strong correlations with certain somatic or non-genital characters like modifications of the cephalic region of male carapaces, shape of the abdomen, relatively length of the legs etc. Accordingly the genus can easily be divided into several natural groups which might deserve generic rank. However, though several available names already exists for those groups, since the study of Bödine & Lovi (1962) they all have been placed into a single genus, viz. *Argyrodes*. It is also beyond the scope of this paper to go deeper in this issue.

#### Abbreviations

CL = length of carapace

LI = length of carapace/length of TI

laA = locking arm A (male palp)

ch = cymbial hook

ta = terminal apophysis

ec = embolic complex

cA = conductor A

oed = opening of entrance duct

All measurements in millimetres



Fig. 1. Left male palps ventrally. Original figures. Scale bars = 0.5 mm.

A. *Argirodes argirodes* - B. *A. ruficornis* - C. *A. flavifronsella* - D. *A. cognatus* -  
E. *A. berycephalus* - F. *A. recurvatus* Saaristo, 1978 - G. *A. pusillus*



Fig. 2. Epigynes ventrally and dorsolaterally. Original figures except A according to Roberts

(1983). Scale bars 0.25 mm. A. *Argirodes argirodes* B. *A. ruficornis* C. *A. flavifronsella* D. *A. cognatus* E. *A. berycephalus* F. *A. recurvatus* G. *A. pusillus*

*Argyrodes argyrodes* (Walckenaer, 1943) (Figs 1A, 2A, 3A-C)

*Leptokala argyrodes* Walckenaer, 1941: 282 (male)

*Argyrodes argyrodes*, Simon 1964: 253 (n. comb.)

—, Saurato, 1978: 133, f. 118–130 (male, female)

**Material examined:** **Mali:** Montagne Passé Road, 2 males, 1 female, 30–10–1975, golf green of the Reef Hotel, male, female, 24–10–1975, and road side near Reef Hotel, 4 males, 5 females, 03–01–1999, all M. Saurato leg. (MZT AA 0 022, 0 023 and 0 782)

**Diagnosis:** A medium sized (CL = 1.3–1.7), fairly dark coloured species with legs of normal length (LI = 0.69–0.79). Male carapace with ocular area raised into a lobe including AMEs and PMEs and below it stands a forward directed clypeal process carrying numerous, unmodified backwards pointing hairs.

According to the morphology of the secondary genital organs *argyrodes* belongs together with *rostratus* and *flavifrons* to the group A. Its male palp differs, among other things, from that of *rostratus* and *flavifrons* by having rounded corners on the triangular apex of the terminal apophysis, *rostratus* has angular corners while *flavifrons* has two narrow, edged patches on the apex of the terminal apophysis. In the epigyne of *argyrodes* the diameter of the more or less circular depressions housing the openings of the entrance ducts is relatively small and they are some four times their diameter apart, *rostratus* has larger depressions which are situated only about their diameter apart while *flavifrons* has more clearly spiral-like depressions situated far apart on prominent bulges.

**Description:** Well described by Saurato (1978).

**Distribution:** This is a Mediterranean-African species found only on Mali (Saurato (1978, 1999)). It seems to be an introduced species which have been able to establish populations only on the lowlands of Mali.

*Argyrodes rostratus* Blackwall, 1877 (Figs 1B, 2B, 4A-C)

*Argyrodes rostratus* Blackwall, 1877: 14 (males)

*A. aspidios rostratus*, Saurato, 1978: 113, f. 131–140 (male, female, n. stat.)

*A. rostratus*, Robens 1978: 923, f. 44–50 (male, female)

**Material examined:** **Arise:** 2 males, 2 females, 1j, 10–17–03–1978, John Rowley leg. and 5 males, 1j, 16–17–07–1975, M. Müllenberg leg. (MZT AA 0 191–193 and 0 310–0 312) and 1 male, 27–02–1999, J. Culbury & E. Andrews leg. (MZT AA 1 268), **Comoros:** on *Nepenthes* web (9), 16 males, 15 female, 1j, March–April 1978, Hugh Walters leg. (MZT AA 0 188–0 190), **Mali:** Various places, Oct. 1975, M. Saurato leg. (MZT AA 0 024–AA 0 027), and Silhouette: outside *Ficus* forest, 4 males, 6 females, 1990, J. Gedlach leg., **Cherrin:** Montagne Passé, 1 male, 1 female, 1j, 12–01–1999, M. Saurato & J. Gerlach leg., and La Passé, 1 male, 3 females, 11–01–1999, M. Saurato leg. (MZT AA 0 187, AA 0 806, and AA 0 807)

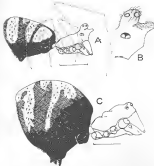


Fig. 3. *Argyrodes argyroides* (Walckenaer, 1837) Original figure. Scale bars = 1.0mm. - A - Male dextrolaterality. - B - Cephalic region of male dextrolaterality. - C - Female dextrolaterality.

**Diagnosis:** A medium sized (CL = 1.6-1.4), fairly dark coloured species with somewhat elongated legs (LI = 0.84-0.86). Male carapace with ocular area raised into a beaked lobe including AMEs and PMEs and below it stands a forward directed, apically dilated clypeal process carrying numerous dark, backwards pointing lancet-like hairs. The abdomen of female usually high conical and the silvery shining corpuscles frequently fused to cover the light areas entirely so that abdomen looks like a small silver piece.

For the structure of the secondary genital organs see above *argyroides*.

**Description:** Well described by Saito (1978) and Roberts (1978).

**Distribution:** This endemic species has been found on Aride; (Bowler *et al.* 1999), Ceasin; (new record), Curieuse; (Roberts 1978), La Digue; (Roberts 1978), Mahé; (Saito 1978, Roberts 1978), and Silhouette; (Roberts 1978, Saito 1999).

**Discussion:** Barber (Saito 1978) considered this species as a subspecies of *A. nephiak* Taczanowski, 1872. At the present I prefer to follow Roberts (1978) in considering it as a full species. *A. nephiak* is a predominantly New World species but is very closely related to an Old World species, viz. *A. argenteus* O. Pickard-Cambridge, 1890. Resolving the relationships between these three taxa requires careful comparative studies of extensive series of the whole *nephiak-argenteus-roseus*-complex, such a revision is badly needed.



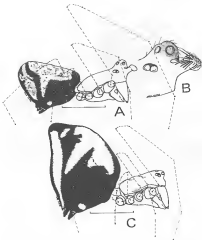


Fig. 4. *Argemone rustrota* Blackwall, 1877. Original figure. Scale bars = 1.0mm. - A. Male dextrorsaterally. - B. Cephalic region of male dextrorsaterally. - C. Female dextrorsaterally.

*Argyodes fascifronsella* Saaristo, 1978 (Figs. 1C, 2C, 5A-C)

*Argyodes fascifronsella* Saaristo, 1978: 114, f. 141-148 (mas, female)

**Material examined:** Mahé: Montagne Poissé Road, holotype male, allotype female, 1 male, 2 female paratypes, 30.10.1975, M. Saaristo leg. (MZT AA 0 029-AA 0 031), and path between La Niole and Mare aux Cochons, 2 males, 2 females, 03. & 17.01.1999, M. Saaristo, Pat Mayot and Maureen Kirkpatrick leg. (MZT AA 0 784,0 786, and 0 787), and Silhouette: 3 males, 1999, Justin Gerlach leg., Ch. Mont Pos., 1 male, 1 female, 14.09.01.1999 and La Paoie, 2 males, 1 male j., 2 females, 19.01.1999, both M. Saaristo leg. (MZT AA 0 197, AA 0 783, and AA 0 785)

**Diagnosis:** Large (CL = 1.5-2.0), handsome, relatively bright coloured species with transverse yellow, silvery and black stripes on abdomen. Legs compressively long (LI = 0.52-0.63). Male carapace with ocular area raised into a lobe including AMs and PMs and below it stands an obliquely upward directed clypeal process carrying numerous short hairs, shape of the clypeal process variable.

For the structure of the secondary genital organs see above *Argyodes*.

**Description:** Well described by Saaristo (1978).

**Description:** Total length mm, length of carapace 1.5-2.0 mm, males larger. Colour pattern of abdomen dirty white, black and silver.

**Distribution:** This endemic species has been found on Mahé (Saaristo 1978, 1999) and Silhouette (Saaristo 1999).

*Argyodes cognatus* (Blackwall, 1877) (Figs. 1D, 2D, 6A-D)

*Epeira cognatus* Blackwall, 1877: 17 (male, female)

*Argyodes cognatus*, Simon 1898: 376 (n. comb.)

—, Saaristo 1978: 13: 116, f. 149-156 (male, female)

—, Roberts 1978: 926, f. 51-56 (male, female)

**Material examined:** Mahé: Montagne Poissé Road, 2 male, 3 female, 27.10.1975, M. Saaristo leg. and various places, 21 males, 28 females, 7.01.-03.01.1999, M. Saaristo, Pat Mayot and Maureen Kirkpatrick leg. (MZT AA 0 028, AA 0 793-0 798, and 0 800-0 803), and Silhouette: Silhouette, outside Pisonis forest, male, 2 females, 7.1999, Justin Gerlach leg. and various places, 24 males, 17 females, 31.09.-19.01.1999, M. Saaristo and J. Gerlach leg. (MZT AA 0 194-0 196, 0 788-0 794, and 0 804-0 805)

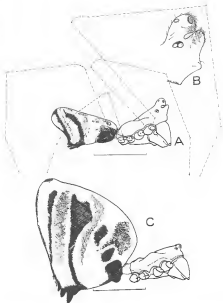


Fig. 5. *Argemone floribunda* Sazima, 1978. Original figure. Scale bars - 2.0mm - A. Male dextralaterally - B. Cephalic region of male dextralaterally - C. Female dextralaterally.

**Diagnosis:** Large (CL = 1.6-1.9), reddish brown or blackish species with long legs (LI = 0.52-0.56). Male carapace with a horn-like, obliquely forward directed elevation devoid of eyes arising from the center of the ocular area. Horn and upper edge of chelae clothed with long, somewhat curved forward pointing hairs. Posterior end of the abdomen of both sexes drawn into a pair of tubercles of variable size.

Bulb of male palp characterized by a relatively short, flat and broad terminal apophysis with rows of denticles at its apex. Epigyne with a trunk-like median elevation which has at its anterior part a small, oval-shaped depression containing the openings for the entrance ducts.

**Description:** Well described by Sazais (1978) and Roberts (1978).

**Distribution:** This is again an endemic species and found on Mahé (Sazais 1978, 1999), Fréatin (Roberts 1978), and Silhouette (Roberts 1978, Sazais 1999).

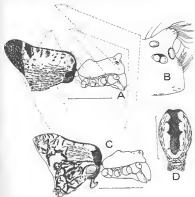


Fig. 6. *Argemone cognata* (Blackwall, 1877). Original figure. Scale bars = 2.0 mm. - A Male chela and palp (dorsolaterally) - B Cephalic region of male (dorsolaterally) - C Female chela and palp (dorsolaterally) - D Abdomen of female (dorsally)

*Argyrodus barycephalus* Roberts, 1983 (Figs 1E, 2E, 3A-C)

*Argyrodus barycephalus* Roberts, 1983: 45, f. 99-102 (male, female)

*Material examined* Silhouette: Proxar forest, Isabud female, 1990, Justin Gerlach leg. (AA 0.199), Jardin Marron, 1 male, 13.01.1999, M. Saurito leg. (MZT AA 0.781), and Chemin Montagne Poide, Isabud female, 09.01.1999, M. Saurito leg. (MZT AA 0.780)

*Diagnosis* Medium-sized (CL = 1.1-1.4), rather gracile species with conspicuously long and slender legs (LI = 0.22-0.28). Colouration relatively pale, light brown with darker sooty markings especially on caudal projection of the abdomen. Male catapage with a large, club-like, forward directed elevation devoid of eyes arising from the center of the ocular area. Abdomen much elongated posteriorly.

Segments of the male palp much elongated. Embolus long, whip-like and terminal apophysis also long with slightly dilated apex bearing numerous scattered denticles. Epigyne with an oval-shaped depression containing the openings for the entrance ducts and lying close to the epigastric furrow.

*Description* Well described by Roberts (1983).

*Distribution* The species was original described from Alaktra soil (Roberts 1983). In addition known only from Silhouette (Saurito 1999).

*Argyrodus recurvatus* Saurito, 1978 (Figs 1F, 2F, 3A-C)

*Argyrodus recurvatus* Saurito, 1978: 11, f. 157-160 (female)

-, Roberts 1978: 928, f. 57-59 (female)

*Material examined* Mahé: Montagne Poide Road, holotype female, 27.10.1975, M. Saurito leg. (MZT AA 0.033) and Silhouette: 1 male, 1 female, Isabud female, 1990 and 1993, J. Gerlach leg. (MZT AA 0.198, 0.199, and 0.823)

*Diagnosis* Medium-sized (CL = 1.1-1.2), gracile species with very long, worm-like abdomen and conspicuously long and slender legs (LI = 0.20-0.26). Colouration pale, light brown with some darker sooty markings on the abdomen. No special modifications on male catapage. The eye region only moderately elevated in both sexes with a large, club-like, forward directed elevation devoid of eyes arising from the center of the ocular area. Abdomen much elongated posteriorly.

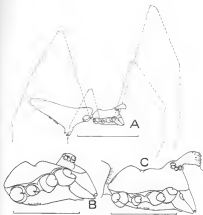


Fig. 7 *Argemone horvathae* Roberts, 1983. Original figure. Scale bars: A = 2.5 mm, B-C = 1.0 mm. - A: Male, dextralateral view - B: Cephalothorax of female, dextralateral view - C: Cephalothorax of male, dextralateral view

Segments of the male palp very much elongated. Embolus rather long with the apical part. Terminal apophysis rather long, flat and conspicuously widening towards its apex. Epigyne with a shallow, median oval-shaped depression with a short and broad transverse ridge-like elevation at its posterior end. Openings on either sides of the ridge-like elevation.

**Description:** Female well described by Saareto (1978) and Roberts (1978). Male (first description) much like female but slightly smaller and legs somewhat longer as usual in *Argyrodes*. Segments of the male palp conspicuously elongated. Embolus relatively long ending into a thin needle-like apical part which is ca. 1/3 total length of the embolus. Terminal apophysis flat, strongly widening apically and bearing a couple of small denticles at its lateral edge.

**Confector:** A transparent, flap-like.

**Distribution:** This endemic species has been found on *Mahé* (Saareto 1978, Roberts 1978) and *Silhouette* (Roberts 1978, Saareto 1999).

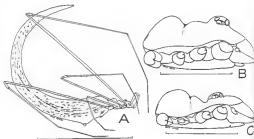


Fig. 8. *Argyrodes roosewardi* Saareto, 1978. Original figure. Scale bars: A = 5.0 mm, B-C = 1.0 mm. - A: Female dextrolaterally. - B: Cephalothorax of female dextrolaterally. - C: Cephalothorax of male dextrolaterally.

*Argemone pusillus* (Saaristo, 1978) (Figs. 1G, 2G, 5)

*Argemone pusillus* Saaristo, 1978: 116, f. 164-169 (female)

—, Roberts 1978: 929, f. 60-64 (female)

**Material examined:** Mahé: Montagne Fosse Road, holotype female, 30-10-1975, M. Saaristo leg. (MZT AA 0 602) and various places, 1 male, 4 females 01-02-01 1999, M. Saaristo, P. Matyot and Maureen Kirkpatrick leg. (MZT AA 0 776-0 779) and Silhouette: several places, 8 males, 4 females, 09-19-01 1999, M. Saaristo and J. Gerlach leg. (MZT AA 0 767-0 775)

**Diagnosis:** Small (CL = 0.8-1.0), dark species with legs of normal length (LI = 0.68-0.76). Volume of the male abdomen (small specimen) about that of male palpal bulbus of *A. gracilicornis*. Abdomen more or less globular with characteristic pattern of silvery patches (Fig. 9B) and small conical elevations posterodorsally. Male with a frontally projecting apical outgrowth bearing a few short hairs.

Sclerites of male palpal bulbus much reduced compared to other *Argemone* species and a  $\sigma$  terminal apophysis very weakly sclerotized, transparent and almost inconspicuous. Epigyna with a median, nose-like elevation.

**Description:** Male well described by Saaristo (1978) and Roberts (1978). Female (first description) essentially like male but larger.

Epigyna with a median, nose-like elevation antero-dorsally far away from the epigastric sulcus. On its either sides shallow, transverse oval-shaped depressions. Openings of the entrance ducts at the median end of these depressions.

**Distribution:** This small endemic species has been found on Mahé (Saaristo 1978, 1999, Roberts 1978) and Silhouette (Saaristo 1999).

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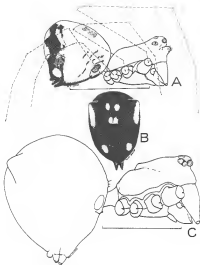


Fig. 9. *Argemone pumila* Sasaki, 1978. Original figure. Scale bars = 1.0mm - A. Male dextrolaterally - B. Abdomen of male from behind - C. Female dextrolaterally

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## *Trilepisium* in Seychelles (Moraceae)

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**Abstract:** The taxonomy of the Seychelles *Trilepisium* species is reviewed, concluding that it is distinct from the nominate Malagasy *T. madagascariense* and should be assigned as a Seychelles endemic, *T. seychellense*. This is one of the most threatened plants in Seychelles, restricted to 4 known adult trees and a small number of saplings and seedlings. Conservation measures are described.

**Key words:** conservation, Moraceae, Silhouette, taxonomy

The Moraceae contains 2 native genera in the granitic Seychelles islands, *Ficus* and *Trilepisium*. *Ficus* is represented by 3 indigenous species (*F. bojeri* Baker, *F. hirta* Vahl and *F. rubra* Vahl) and one endemic subspecies (*F. reflexa* Thunb. *seychellensis* (Baker) Berg). *Trilepisium* is represented by a single species, originally described as endemic ('*Boegenia gossweileri*' - Baker 1877) but more recently referred to *T. madagascariense* DC. (Berg 1977). This species was originally a major component of the low-land and mid-altitude forests, being described from Mahé and Praslin islands in 1768 (Gerlach 1995) and 'In all the islands' (Horné in Baker 1877). It is now restricted to 4 mature trees on Silhouette island. As the most recent taxonomic revision considered this population to be non-endemic and the species as a whole is not considered to be globally threatened it has received little conservation attention. The Nature Protection Trust of Seychelles considers the Seychelles population to be critically endangered (Gerlach 1997) and has an active programme of small-scale propagation. In the light of the threatened status of the Seychelles population it is important to ensure that the current taxonomic position of this population is correct. 14 species are currently synonymized within *T. madagascariense* and the monotypic nature of *Trilepisium* has been suggested to be doubtful (Friedmann 1994), accordingly the taxonomic position of the Seychelles population is reviewed here.

### Variation in Afro-Malagasy *Trilepisium*

*Trilepisium madagascariense* is distributed throughout tropical Africa, Madagascar and Seychelles (Berg 1977).

As noted by Berg (1977) the African populations of *Trilepisium* show relatively little variation. Only three significant points of variation are detectable: leaf width, floral dimensions and fruit dimensions. Leaf width appears to be clinal, with narrower leaves in the east of the range. This does not correlate with any other character and has no taxonomic implications. Anther length is also clinal, with longer anthers in the east than in the west. Fruit dimensions appear to be randomly distributed and can be attributed to individual variation. On the basis of any lack of correlation between these variations and any clear breaks in the clinal patterns the African *Trilepisium* can be considered to be monotypic.

The Malagasy population is highly variable, particularly in leaf morphology. There are no clear correlations with other morphological or environmental features and the cause of

variation is difficult to determine. The anthers are relatively long (0.5-1.5 mm, compared to 0.3-1.0 mm for most of the African material) but show no clear pattern of variation.

Variations in leaf morphology on Madagascar were classified into 3 main groups by Berg (1977):

- Group A - rigidly coriaceous leaves, apex obtuse, base acute, fruit <10 mm. 10% of specimens were of this form.
- Group B - coriaceous leaves, >10 cm, apex long-acuminate, base obtuse, fruit >10 mm. 10% of specimens were of this form.
- Group C - leaves variable, small or medium (usually <10 cm long), apex long or shortly acuminate. This group is intermediate between groups A and B and contains the majority of specimens (60%).

All Malagasy specimens are united by the presence of sparse, short acuminate hairs on the petioles, which distinguish them from the African population. Friedmann (1994) considered the Malagasy population to consist of 3-4 distinct species. A full revision of the Malagasy material is clearly necessary to separate genetic and environmental influences on morphology.

#### Morphology of the Seychelles population (Fig. 1)

Berg (1977) noted that the Seychelles specimens resembled the Malagasy group A in leaf characters although Friedmann (1994) considered them closer to the African specimens, especially those of '*Bongivia engolensis*', noting specifically that the leaves of Seychelles specimens were considerably longer than those of the Malagasy type.

Friedmann (1994) describes Seychelles material as having oblong-oval leaves, shortly acuminate at the tip, obtuse or sub-cuneiform at the base. Dimensions 8-12(-17) × 3.5-5(-5.5) cm, margins entire, glabrous. Petiole 0.8-1.5 cm, striates 2, one rolled round the other, amplexicaul, to 6.5 mm long. This differs from Malagasy material in the glabrous petioles and most closely resembles east African material in leaf proportions. The basal leaf nerves are relatively well developed, unlike most Malagasy specimens, being closer to the African material.

The flower is typical of *Trilepium*, being indistinguishable from Afro-Malagasy material in all but anther characters. The Seychelles anthers are 0.4-0.5 (-0.6) mm long compared to African anthers of 0.3-1 mm and Malagasy anthers of 0.3-1.3 mm, thus being at the lower end of the Malagasy range and most closely resembling the anthers of central African plants. The stigma is not coiled unlike most Afro-Malagasy specimens (although this is variable).

From this comparison it appears that Seychelles *Trilepium* are closer to central or south-west African than to Malagasy specimens. As the Malagasy specimens differ from those of Seychelles and Africa by having acuminate hairs on the petioles, smaller, more coriaceous leaves and a tendency towards having longer anthers, *Trilepium* can be divided into at least two main groups: Madagascar and Africa-Seychelles. The African and Seychelles populations are distinguished by the larger, more coriaceous leaves of the Seychelles plants.

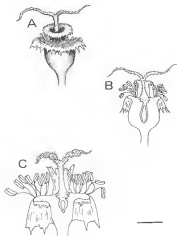


Fig. 1. *Trilepisma madagascariense*. Scale bar 1 mm

A) whole flower (Seychelles), B) flower longitudinal section (Seychelles), C) flower longitudinal section (Madagascar)

As the Malagasy material includes the type of *T. madagascariensis* the Seychelles specimens should be removed from its synonymy. In order to reflect this, Baker's (1877) name for the Seychelles population should be resurrected and altered to *Drilepsum gymnosdrum* (Baker) comb. nov.

#### Distribution and ecological position of *Drilepsum gymnosdrum*

The first records of *T. gymnosdrum* in Seychelles date from 1768. Descriptions of a tree with a latex drying brown correspond closely to this species (Lacouture, 1984). This species was recorded throughout the lowland forests on Mahé and Praslin, it appears to have been an abundant species in the lower areas. The next reference by Horne (in Baker 1877) "in all the islands", this is in agreement with the 1768 records but too imprecise to be useful. The next record collected a specimen from "mountain forest" (label on Thomsen 96), a description used by the Percy Sladen Memorial Expedition of 1905 to refer to the forests between Cascade and Montagne Plateau on Mahé where Thomsen's estate was situated. The only subsequent record is Friedmann (1986, 1994) who could only locate the species on Silhouette.

The current distribution of *T. gymnosdrum* is highly restricted. Mature trees have only been located at two sites, on the south-west slope of Mont Pot à Eau (Grand Congoman in Friedmann 1994) and between Mare aux Cochons and Mont Darban, where only 4 trees are present. These sites are mid/high-altitude forest at 300m and 600m above sea level respectively. Seedlings are frequently located on the Jardin Maïson path and less frequently on the Chemin Montagne Poisson. A single sapling approximately 2m tall is present on the latter path at about 300m above sea level.

The early historical records of this species as being common in lowland forests is in marked contrast to the records since 1905 and the present-day distribution. This is probably a consequence of the deforestation of lowland areas, the high-forest distribution being a relict. Seedlings removed from Jardin Maïson and planted at La Pausse 30m above sea level have established easily, supporting the view that this species is adapted to lowland habitats. Seedlings left growing in the path have not been recorded surviving more than a few months (1 year in one case). These were growing in the compacted soil of the path and in loose, humus rich soil to the sides. Rainfall at these sites is high and the canopy closed, resulting in very low light levels. Those planted in lowland areas are also in comparatively dry humus rich sites. The canopy is more open and light penetration is high. Under these conditions survival is high and growth is rapid.

The dispersal mechanisms of this species are not known. The 10mm diameter single seeded fruit appears to be adapted to bird dispersal. The distribution of seedlings apparently distant from parent trees supports the suggestion that birds such as the endemic Seychelles bulbul (*Hypsositta c. sechellarum*) and the alien Indian mynah (*Acridotheres tristis*) are the main dispersal agents. Mynahs are uncommon in the high forests but both species are abundant in lowland areas on Silhouette.

#### Conservation

The highly restricted range of the species and the scarcity of mature trees makes this one of the most threatened of all Seychelles trees. Using the IUCN Red List criteria (IUCN

1994) it can be classified as Critically Endangered on the basis of the extremely small number of mature individuals (criterion D). Several of the Seychelles plants have extremely small populations although none are quite as restricted as *T. greenandruoi* (e.g. *Melchioria oppositifolia* and *Drypetes rosula*: 50 trees, *Psychotria silhouettensis*: 6 known plants).

The 4 mature trees and the sapling on the Chenet Montagne Passes are not at risk from any known threats. They are found in semi-natural forest areas on Silhouette which, although not given official protection, is managed for conservation purposes by The Nature Protection Trust of Seychelles in conjunction with the Islands Development Company. All seedlings located to date have been in sub-optimal locations and have been at risk from trampling by people walking on the paths or by cutting during path maintenance operations. Since July 1999 all such seedlings have been removed. These are grown by the NPTS at La Passe until they reach approximately 40cm in height. Two plants have reached this height to date and were planted out in a suitable area in January 2000. The area selected is an area of lowland palm forest being restored after clearance of stems and coconuts (*Cocos nucifera*). In this area both plants have grown quickly and now reach 48.5-54cm. A further 3 plants will be planted out in the near future in adjacent areas.

Using this small scale propagation approach it will be possible to produce a steady growth in the *T. greenandruoi* population, keeping in pace with lowland habitat restoration. Proposed expansions of the habitat restoration work of the NPTS Silhouette Conservation Project may enable the rate of propagation to increase, although the limited parent population is an unavoidable constraint.

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# Protozoa in biogeocenoses of some Seychelles Islands: soil shell amoebae (Testaceae)

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**Abstract.** Testacea were found to be an essential component of amoebians in biogeocenoses of Seychelles. 44 species and subspecific taxa (10 families, 18 genera) were isolated from 40 samples (mainly soils and plant litter). *Cosmopodium curvirostris* and *Stromboceros* prevailed, 8 species were regarded as representatives of the tropical group. Testacean communities in arid and high granite islands were found to be different.

**Key words:** Protozoa, fauna, population, abundance, distribution, ecological preferences, tropical species

## Introduction

There is an extensive literature dedicated to different animal groups in arid ecosystems, but unicellular soil inhabitants are given little, if any, attention. This is probably due to the fact that in the beginning of the XX century Protozoa were often considered as occasional and inactive in soil habitats. Furthermore, microscopic organisms are far more difficult to handle than larger metazoans, in their identification and isolation from such a dense and opaque medium as soil. Their great importance in soil biological economy is now in no doubt and is stressed by many authors (e.g., Barnforth, 1980; Foushee, 1987; Gelwick, 1993). Being an essential component of soil biota, Protozoa represent the base of heterotrophic eukaryotic food webs, consuming a significant portion (> 50%) of bacterial productivity, enhancing nutrient cycles and energy flows in soil ecosystems to the benefit of microorganisms, plants and animals (Foushee, 1999). Their high reproductive rate, short life and generation time ensure a notable biomass, comparable with that of earth-worms, and about 10% of total carbon input produced in respiration process (Sleigh, 1989).

In this paper I present the results of protozoological investigations, carried out in 1984 in the course of a multi-disciplinary expedition of the research vessel "Akademik Alexander Vinogradov" to the Seychelles Archipelago. The expedition was undertaken by the USSR Academy of Sciences as a contribution to the UNESCO "Man and Biosphere" Programme, project 7 - "Isular ecosystems and their rational use". According to the available literature, the object of our study - shell amoebae (Protozoa: Rhizopoda: Testacea) - had not been given special attention in Seychelles, except for occasional collections on Mahé island (Wardle, 1912). Other regional data include those obtained by Hennay & Chardon (1988) for Mauritius, and by Declercq (1956, 1959) for Madagascar.

Investigation of this rhizopod group, of interest in itself, provides more information on many protozoological and ecological problems than do other protozoans. Testaceans build biologically useful hard shells, which remain intact in soil for a long time. So fauna, population and community structure can be appraised even when the cell itself is dead. The proportion of particular life forms (types of shell morphologies) in different habitats make it possible to observe visually the influence of different ecological situations on testacean complexes. Faunal and ecological investigation in Seychelles presents additional data on the pro-



graphical distribution of Testacea. Although mostly cosmopolitan, some testacean taxa are restricted to equatorial regions. The irregularity of, and the reason for this distribution of allochthonous uniaquiferous animals has attracted much attention and has been widely discussed over the last decades.

Testacean populations are considered in the present paper with special reference to faunal composition, species distribution in specific insular ecosystems, colonization of small islands and are discussed in terms of common patterns of protozoans and mesozoa distribution.

#### Localities, materials and methods

Protozoological investigations were performed on 7 islands. According to their geomorphology and landscape, they belong to 3 groups - high mountainous granite and syenite islands (Silhouette, Fohite, Mahé, La Digue, the altitude up to 760 m asl, area up to 190 km<sup>2</sup>), low atolls of reef origin (Poivre, Farquhar, up to 5 m asl, 5-15 km<sup>2</sup>) and elevated atolls (Assumption, up to 12 m asl, 15 km<sup>2</sup>). Climatologically the islands are subdivided into northern (Silhouette, Mahé, Fohite, La Digue, Poivre) and southern (Assumption, Farquhar) groups. The former characterized by equatorial marine climate with precipitation almost the year round, with a poorly defined short dry period, the latter - situated in the tropical marine climatic zone with a 7-8 month dry period and strong aridization. Natural complexes of low atolls are simple and homogeneous: strand forests of pantropical and naderal plants (*Casuarina*, *Scaevola*, *Prosopis*) are usual on the beaches, with coconut palm plantations in the centre of the islands. The islands are flat, the relief is not differentiated and humus-carbonate soils have short (some cm) accumulative profiles. Trade winds and intensive wave action form a specific substratum: banks of algae (Southern Poivre).

The relief of Assumption is a strongly karsted limestone surface. The soil formation in the coastal zone is at its initial stages (crusts of algae, "desert varnish"). In the marine terrace, soil is sandy humus carbonate with high pH, similar to that of low atolls. The xerophytization of plant communities (scrub) is related to the aridity of the island.

The mountainous relief of Silhouette results in local differentiation of the amount of precipitation. The level of moisture condensation is observed at about 600m altitude, being more than 1600 mm annually. Four vertical vegetation zones can be discerned. Most tropical forests (*Dalmania*, *Ficus*) with abundant epiphytes and mosses, covering trunks still remain on almost inaccessible elevations (760m). The other high granite islands are covered with secondary tropical forests mainly with *Calophyllum* and *Coussarea*. Red-yellow soils of mountain tropical forests with varying humidity prevail, as well as soils of brown series.

The material was collected in the main habitats. The biotopes, recurrent in all the islands (such as litter under *Casuarina*, soil under palm plantations, etc.), as well as specific (algal crusts, "suspended soils") and optimal (moss epiphytic epibioses) for testacean development were involved (Table 1). Samples were taken at 5 points of homogeneous plots, averaged and treated according to the adopted technique (Korotova & Goltsov 1977). Triplicate stained smears were prepared and examined microscopically, the water suspension of the substrata were examined additionally to reveal rare and scanty forms. The depth of sampling in horizons A0 (plant litter), A1 (humus layer) or not differentiated A0A1 was up to 3-4cm. The number of testaceans (pedicling amoebae and empty shells) was recorded as individuals

Table 1. Sampling sites

Island, number of samples	Sample number & substrate characteristics
Island 4	1 - ADAI under <i>Casuarina</i> , the Agricultural station, slope ca. 100 m altitude, 3 - cortical moss on <i>Bomarea</i> , same site, 5 - brown tropical soil, vicinity of the town of Victoria, secondary forest, <i>Casuarina</i> , slope, ca. 300-350 m, 6 - human-modified trunks of trees, same site
Peperu (north & south), 8	3 - cortical moss on a palm, plantation, 6 - substrate from leaf axils of palm, same site, 7 - ADAI under <i>Casuarina</i> , beach, 8 - "algal" bark (pieces of <i>Thalassia</i> ), same site, 9 - human in the base of a dead palm, plantation, 10 - AI, human-carbonate soil, same site, 11 - fertilized soil, same site, 12 - phosphorized soil, vacant, same site
Isanapiton, 7	13 - human in under bark, coast, 14 - human accumulation under chambers of <i>Coprosma</i> , sandy, 15 - filamentous algae on walls of a burnt rock, 16 - "crusts" (blue-green, soft lobes) on limestone plates, 17 - algal bark, beach, ADAI under <i>Casuarina</i> , coast, 18 - ADAI under <i>Casuarina</i> , coast, 19 - AI, human carbonate soil, plantation
Yacupier (north & south), 6	20 - apical moss, coast, 21 - ADAI under <i>Bomarea</i> , Flavia, the center of the island, 22 - AI, human carbonate soil, plantation, 23 - fertilized soil, same site, 24 - AI under <i>Casuarina</i> , coast, 25 - substrate from leaf axils of a palm, plantation, 26 - algal bark, beach
Silivuetia, 9	27 - human on a temporary water course, the 1st plant belt, 28 - same site, on open fields along channels, the 2nd belt, 29 - decomposed wood, trunks of dead palms, same site, 30 - apical moss, same site, 31 - red-yellow soil under <i>Fabroa</i> , <i>Leucaena</i> , same site, 32 - ADAI under <i>Adiantum</i> , the 3rd belt, 33 - substrate in leaf axils of <i>Leucaena</i> , same site, 34 - ADAI under <i>Gleichenia</i> , <i>Colophyllum</i> , thick cortical moss with epiphytic ferns, under on Flavia (the collected sample of substrate in the 4th belt), 35 - human stripes on concrete, coast exposed to storms
Filiciti, 1	36 - ADAI under <i>Colophyllum</i>
La Digue, 4	37 - ADAI, secondary forest, <i>Casuarina</i> , slope, ca. 100 m, 38 - human under grass stems, same site, 39 - cultivated soil, cabbage field, the Agricultural station, 40 - early-opening compost, same site

$g'$  - oven dried weight of the substratum, its field humidity being determined. The total mass of living cells was calculated by the formula:  $P = k \times n \times d \times M$ , where "k" - the mass of the cell, "n" - the number of protozoans  $g'$  - oven dried weight of the substratum, "d" - the volume weight (the specific weight) and "M" - the volume of the substratum. The average mass of the one cell ( $23.3 \mu m^3$ ) was estimated as the mean between small (about 25-45 microns) and large (50-100) organisms (for details see Gelhaar *et al.* 1980)

## Results

A wide range of habitats (40 samples altogether) collected on islands of different size, origin and ecological status provided reliable data on testacean species diversity in soil and other natural habitats.

### Fauna and population

94 species and subspecific testacean taxa (10 families, 18 genera) were found (Table 2). The most abundant was the Ceratomyxidae family (34 species, over 34% of the fauna), the Hydrophorinidae and Euglyphidae were also rather diverse - 17 and 12 species (18 and 12.5 %, respectively). Other families were monogeneric or included two genera, with few species. Rare Acanthidae (*Acanth*) shells lost their shape and clear species characters. Diffugiidae

(*Diffugia*) were represented by a sole specimen of *D. oblonga* and some small *Diffugia* sp. Identification of variable *Centropycidae* (*Centropycis acrophila*, *C. cincta*) in some cases was not quite certain because of "leathery" appearances of shells in crusts of algae on the soil surface of Assumption, which lacked sand grains, usually used for shell building. The identification of *Cyclopyxis aestivus*, *C. trilobata*, *Trigonopyxis arcata*, *T. annata* was also difficult due to great variation of test size and form of pseudostome.

The distribution of Testacea in island biotopes is fairly non-homogeneous (Fig. 1): representatives of *Cyclopyxis* live almost everywhere (over 80% of samples), *Centropycis* is very frequent, *Phryganella* and *Euglypta* occur in about 50% of samples, *Parasquadrula*, *Trigonopyxis* and *Trachelinglypta* only in 15%. Most species were rare (found in 1-10% of samples) (Fig. 2, A). High frequency (30-80%) was observed only for 6 species, the most common being *Cyclopyxis euryzona* and *Centropycis acrophila*.

The distribution of samples according to the shell numbers is shown in Fig. 2, B. The majority of samples (80%) were found to have no more than hundreds or one-two thousand shells, and the high proportion (63%) of the species belongs to the group with rare occurrence.

The species diversity in samples varied from 1 to 48 forms, mostly moderate (20) or low (10), the maximum (35-48) occurring on Mahé and Silhouette (Table 3). Similarly, maximum abundance (about  $25 \times 10^6 \text{ g}^{-1}$ ) was recorded on these same islands. In samples with low or moderate abundance (Assumption, Parakaar) the species were represented by eurybionts of standard acrophilous complex (*Centropycis acrophila*, *Cyclopyxis euryzona*, etc.) and some stenobiontic forms, in samples with higher abundance (Silhouette) representatives of Hyalospheridae reached up to 50% of the population. There was only one case of superdomination (*Phryganella parvifera* in frames accumulation in the trunk of a dead tree on Mahé). The local development of this species was the reason for the extremely high number of shells in the sample (about  $73 \times 10^6 \text{ g}^{-1}$ ), also dominating the living cells (over 80%) and making up a relatively high biomass ( $0.63 \text{ gm}^{-2}$ ), the highest value in all the biotopes studied. In other habitats the biomass was low, making up several dozen  $\text{mg m}^{-2}$  of substrate. The proportion of trophically active cells varied by 2-28% in the sample.

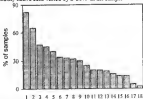


Fig. 1. Frequency of Testacea in surveyed habitats: 1 *Cyclopyxis*, 2 *Centropycis*, 3 *Phryganella*, 4 *Euglypta*, 5 *Platystrophia*, 6 *Helicospira*, 7 *Tricoma*, 8 *Pseudovermetus*, 9 *Bullinaria*, 10 *Arcella*, 11 *Nobelia*, 12 *Hyalospherina*, 13 *Quadrula*, 14 *Trigonopyxis*, 15 *Trachelinglypta*, 16 *Parasquadrula*, 17 *Diffugia*, 18 *Euglyptella*.

Shell amoebae, found on the islands, are mostly (more than 85% of the species) widely distributed, common forms. They are supplemented by some species with a limited range in Southern hemisphere ("Gondwana", "southern" or "tropical" forms - according to Bonnai, 1977). There are 8 such forms in our material.

- 1 *Centropyge latidiffracta* - Silhouette: substrate in leaf axils of *Lodicea*, primary tropical forest, 400-500 m asl, AOA1 under *Ocotea*, *Calophyllum*, thick cortical moss layer with epiphytes on *Ficus*, primary tropical forest, more than 700 m asl, frequency 5% of the total number of the samples.
- 2 *C. senodiffracta* - Silhouette: as (1), Mahé: vicinity of the town of Victoria, brown tropical soil under secondary forest with *Cinnamomum*, 300-350 m asl, Félicité: AOA1, secondary forest, under *Calophyllum*, 10%.
- 3 *Cylogynis dulcis* - Silhouette: as (1, 2), Mahé: as (2), Félicité: as (2), La Digue: humus under green moss, secondary forest with *Cinnamomum*, about 100 m asl, 12.5%.
- 4 *C. intermedia* - Silhouette: AOA1 under *Adenanthera*, primary tropical forest, 400-500 m asl, substrate in leaf axils of *Lodicea*, the same site; Mahé: as (2, 3), La Digue: AOA1, secondary forest with *Cinnamomum*, about 100 m asl, 10%.
- 5 *C. rhinostoma* - Silhouette: substrate in leaf axils of *Lodicea*, the same site as (1, 4), Mahé: local humus accumulation in dead trunks of trees, the same site as (2), 5%.
- 6 *C. mephastoma* - Silhouette: as (4), Mahé: as (2, 3, 4), 5%.
- 7 *Quadrivella tropica* - Silhouette: as (1, 2, 3), Mahé: as (2, 3, 4, 6), La Digue: as (4), 10%.
- 8 *Pseudovermetaria deharvengi* - Mahé: as (2, 3, 4, 6, 7), Félicité: as (2, 3), Porée: palm plantation, humus carbonate soil, the same - fertilized variant, Assumption: local humus accumulation under rhizomes of *Copris*, scrub, palm plantation, humus carbonate soil, Farquhar: AOA1 under *Bernardia*, *Ficus*, the centre of the island, 10%.

The species, as is shown by their frequency (mostly 5-10% of the total number of the samples), occur irregularly and sparsely, excluding *P. deharvengi* more common on shells.

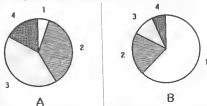


Fig. 1. Occurrence (A) and number (B) of Teretacea in samples: 1 - proportion of species found in 1-10% of the samples (for A), proportion, %, of samples with less than 100 shells (for B), 2 - in 11-20% and with 100s of shells, accordingly; 3 - in 21-30% and with 1000s of shells, 4 - < 30% of the samples and with 10,000s of shells.

Table 2. Distribution of Testacea in biotopes of investigated islands

Family/species	Sample number	Frequency *
<b>Arvaliidae</b>		
<i>Arvalia armata</i> Onoff	14	2.5
<i>A. antissa</i> Piss	10, 14, 19, 21, 26, 27, 29	17.5
<i>A. emulata</i> var. <i>aplanata</i> Dall	14	2.5
<i>Arvalia</i> sp.	1, 14, 21, 27, 29	15.5
<b>Ceratopysidae</b>		
<i>Ceratopys emulata</i> (Ehrbg.) Sower	1, 10, 27, 32, 33	12.5
<i>C. aculeata</i> var. <i>mutata</i> Van Oys	29	2.5
<i>C. aculeata</i> (Dall)	1-5, 10, 14, 15, 18, 19, 21, 23, 27, 28, 30-34, 36-38	68.0
<i>C. aculeata</i> var. <i>granata</i> Sower	3	2.5
<i>C. aculeata</i> var. <i>mutata</i> Charlot	21	2.5
<i>C. aculeata</i> var. <i>aplanata</i> Dall	27	2.5
<i>C. aculeata</i> (Müllb.) Dall	1-5, 10, 27, 28, 30, 36, 37, 39	32.5
<i>C. aculeata</i> (Ehrbg.) Piss	3, 6, 27, 34	10.0
<i>C. aculeata</i> (Piss.) Dall	27, 28	5.0
<i>C. aculeata</i> Leidy	14, 21, 23, 33	10.0
<i>C. aculeata</i> var. <i>mutata</i> Sower	11	2.5
<i>C. elongata</i> (Piss.) Thomas	3, 5, 10, 14, 27, 30, 33, 37, 38, 39	22.0
<i>C. elongata</i> Piss	19, 21, 34	7.5
<i>C. laevigata</i> Sower	33, 34	5.0
<i>C. mutata</i> Dall	4, 33, 34, 37, 39	17.5
<i>C. orbicularis</i> Dall	27	2.5
<i>C. plagiata</i> Sower & Thomas	3, 4, 14, 21, 27	12.5
<i>C. plagiata</i> var. <i>mutata</i> Sower & Thomas	18, 19, 24, 31, 33, 37, 38	20.0
<i>C. plagiata</i> (Piss.) Dall	2	2.5
<i>C. spicata</i> Cash	31	2.5
<i>C. tenuicostata</i> Sower	1, 21, 34, 36	10.0
<i>C. cylindrica</i> (Dall.) Thomas	21	2.5
<i>Cyclogaster emulata</i> Sower & Thomas	3, 4, 29, 32, 34, 37, 38	22.5
<i>C. orbicularis</i> Charlot	4, 33	5.0
<i>C. alata</i> Sower-March	3, 33, 34, 36, 38	32.5
<i>C. mutata</i> Dall	1-7, 9, 12, 14-16, 19-23, 27, 28-39	80.0
<i>C. mutata</i> var. <i>gastrea</i> Sower & Thomas	3, 29, 33, 37, 38	32.5
<i>C. mutata</i> var. <i>parvula</i> Sower & Thomas	10	2.5
<i>C. intermedia</i> Kuffner	3, 32, 33, 37	10.0
<i>C. kufli</i> Dall	3, 20, 32, 33, 39	12.5
<i>C. kufli</i> var. <i>aplanata</i> Sower & Thomas	3, 10-12, 14, 18, 20, 28, 31, 37, 38, 40	30.0
<i>C. intermedia</i> Sower	4, 33	5.0
<i>C. applanata</i> Sower	3, 32	5.0
<i>C. orbicularis</i> Dutton	29, 37, 38	7.5
<b>Triopopyidae</b>		
<i>Triopopya aculeata</i> (Leidy) Piss	4, 33	5.0
<i>T. mutata</i> Sower	4, 33	5.0
<b>Plagiopysidae</b>		
<i>Plagiopys aculeata</i> var. <i>granata</i> Thomas	3	2.5
<i>P. aculeata</i> Thomas	3, 36, 37, 39	10
<i>P. aculeata</i> var. <i>elongata</i> Sower & Thomas	36	2.5
<i>P. parvula</i> Sower	2, 3, 10, 11, 22, 27, 28, 30, 36-39	48.0
<i>P. mutata</i> Sower	1, 21, 36	7.5
<i>P. parvula</i> Thomas	2, 3, 10, 36	10.0
<i>P. parvula</i> var. <i>elongata</i> Sower	27	2.5
<i>Palaemonetes gracilis</i> Thomas	3, 4, 10, 14, 16, 21, 34, 28, 35	30.0

Family, species	Sample number	Frequency *
<b>E. rubens</b> Pers.	15	2.5
<b>Pyralidae</b>		
<i>Dactyloctenoides</i> (Ehrbg.)	27	2.5
<i>Dactyloctenoides</i> sp.	14	2.5
<b>Hydrophoridae</b>		
<i>Hydrophorus</i> (Ehrbg.)	27,30,33,39	12.5
<i>H. depressus</i> Pers.	3,30,33,34	10.0
<i>H. subcylindricus</i> Pers.	30	2.5
<i>H. maculatus</i> Pers.	3,34,37	7.5
<i>H. punctatus</i> Dall.	3	2.5
<i>H. punctatus</i> var. <i>minor</i> Dall.	3,34,38	7.5
<i>Quadrula</i> (Ehrbg.)	34	2.5
<i>Q. punctatus</i> Villalp.	27,28,31,34,37,39	15.0
<i>Q. punctatus</i> var. <i>insignis</i> Villalp.	3,14,34,37	10.0
<i>Q. punctatus</i> var. <i>insignis</i> Villalp.	3,23,34,37	10.0
<i>Hydrophorus</i> (Ehrbg.)	14,39	5.0
<i>H. punctatus</i> Pers.	3,29,34,38	10.0
<i>H. punctatus</i> Pers.	3,29,30,31,38	12.5
<i>H. punctatus</i> Pers.	30,34,37	7.5
<i>Hydrophorus punctatus</i> var. <i>insignis</i> Villalp.	30	2.5
<i>H. punctatus</i> var. <i>insignis</i> Villalp.	14	2.5
<i>H. punctatus</i> Pers.	3,20,21,26,27,30,30,36,39	22.5
<b>Parasitidae</b>		
<i>Parasitidae</i> (Ehrbg.)	26,33	5.0
<i>P. punctatus</i> (Ehrbg.)	34,15,23,26,31	15.0
<b>Phryganidae</b>		
<i>Phryganidae</i> (Ehrbg.)	3,5,7,10,14,16,19,21,21,31,34,36,38	42.5
<i>Ph. punctatus</i> Pers.	3,4,14,29	10.0
<b>Euglossidae</b>		
<i>Euglossa</i> (Ehrbg.)	27,30,31,33,36,37	15.0
<i>E. punctatus</i> Pers.	3,34,34,39	15.0
<i>E. punctatus</i> Pers.	3,30,34,37	10.0
<i>E. punctatus</i> Pers.	3,27,30,34	10.0
<i>E. punctatus</i> Pers.	1,3,19,30,31,33,34,36,38	22.5
<i>E. punctatus</i> Pers.	36,37	5.0
<i>E. punctatus</i> (Ehrbg.)	4,3,33	7.5
<i>E. punctatus</i> (Ehrbg.)	1,3,14,31,37	12.5
<i>E. punctatus</i> Pers.	3,9,27,30,31,33,34,36,40	30.0
<i>Euglossa</i> sp.	3	2.5
<i>Euglossa</i> (Ehrbg.)	1,2,21,27,33,34,37	17.5
<i>Euglossa</i> (Ehrbg.)	33	2.5
<b>Tithonidae</b>		
<i>Tithonidae</i> (Ehrbg.)	3,31,32,34, 37,38	15.0
<i>T. punctatus</i> Pers.	27,34	5.0
<i>T. punctatus</i> Pers.	3	2.0
<i>T. punctatus</i> Pers.	30,33	5.0
<i>T. punctatus</i> Pers.	1,2,3,27,30,30,34,36,38	30.0
<i>T. punctatus</i> Pers.	3,20,21,26,30,31,34,36,37	25.0
<i>T. punctatus</i> Pers.	3,34	5.0
<i>T. punctatus</i> Pers.	3,34	5.0
<i>Pseudomutinus</i> (Ehrbg.)	7,10,12,14,19,21,23,34,36	27.0
<i>P. punctatus</i> Pers.	1,7,10,12,14,19,21,36	30.0

\* % of the number of samples, \*\* species of uncertain taxonomic position

Table 3. Main characteristics of communities of the Testacea.

Island	Sample number	Shell abundance *	Number of species	% trophically-active species	Biomass (g m <sup>-2</sup> )
Mahe (88 species) 1	2	2.54	19	-	-
	3	3.22	6	11.6	0.025
	5	5.07	48	4.9	0.090
	4	72.90	10	7.6	0.45
Folven (88)	5	18.00	5	2.2	0.025
	6	0.17	1	-	-
	7**	0.17	3	-	-
	9	1.10	3	-	-
	10	0.61	10	-	-
	81	1.90	7	-	-
Assumption (28) 14	82	0.32	3	-	-
	673	0.73	20	-	-
	15	0.85	2	-	-
	16	2.20	9	12.6	0.015
	18	0.20	3	-	-
Farquhar (22)	19	0.60	11	-	-
	20	1.20	4	28.5	0.015
	21	0.94	18	7.5	0.105
	22	0.29	3	-	-
	23	1.20	4	-	-
	24	0.07	2	-	-
Silhouette (88) 25	26	0.20	3	-	-
	27	24.40	31	1.2	0.035
	28	0.40	6	-	-
	29	1.60	9	8.6	0.010
	30	12.13	16	7.3	0.063
	31	2.04	18	9.7	0.013
	32	1.23	18	20.8	0.058
	33	13.08	30	9.1	0.078
Folven 14 (22)	34	7.28	33	4.7	0.060
	35	0.06	7	-	-
	36	2.26	22	9.8	0.020
	37	8.97	30	5.3	0.028
La Digue (45)	38	1.0	16	25.0	0.050
	39	17.9	23	2.7	0.093
	40	0.81	3	-	-

\*  $\times 10^3$  g oven-dried substrate; \*\* in samples 8, 13, 17, 25 no testaceans were found

### Species distribution

Different patterns of testacean chorology were observed in low biogenic and high genetic islands.

Islands of reef origin. More than 50 species were found altogether in all atoll biogeocoenoses. Table 4 lists the species recorded in the most common and characteristic habitats in the atolls - palm plantation soils and beaches. The testacean population was characterized by calciphilous species *Balanus* *gracilis*, *Pseudovermetus* *calcarata*, *Parasquadrula* *argentea*, some *Helicovera*, *Hydrobia* *ulmaria*, being supplemented with few eurytopic of aerophilous complex, such as *Corbicula* *aerophila*. Even algal banks, moved by wave action and mixed with coral sand (Farquhar, sample 26) contained 2-3 species

(*Heliosperma sylvatica*, *Paraquadrula irregularis*, *P. globulosa*)

Despite the extreme aridity, the species assembly on Assumption was much the same due to substrate similarity, sometimes one more calciphilous species - *Hydropluteus insularis* - was recorded. Filonina, even such common forms as *Euglypta laevis* and *Tricoma laevis*, were rather rare.

The species diversity in biogeocoenoses of biogenous islands was limited to 10 forms, rarely up to 20, their abundance was usually low (a few hundred — 1-2 ths of shells g<sup>-1</sup>). The trophically active organisms were found in a few soil samples (Table 3).<sup>1</sup> At the same time they accounted for over 12% in crusts of algae (sample 16) on the soil surface of Assumption (surprising for this very dry and extremely infertile substratum), and about 28% in Farquhar (sample 20). In stalk living cells were recorded in populations of *Arceia antennata*, *Centropages asperifolia*, *Cyclopoides eurytomus*, *C. labilis*, *Heliosperma sylvatica*, *Quadrulella symmetrica*, *Paraquadrula irregularis* and *Euglypta laevis*.

In young palm plantations, along with natural humus carbonate soil, its cultivated (fertilized) variant was examined (e.g., sample 11 in Peiros). The layer of palm leaves and

Table 4. Some characteristic testacean groups in the substrata of tropical islands

Species	Pacific Ocean	Indian Ocean
<i>Islands of real origin, calciphilous group</i>		
<i>Bulinulana gracilis</i>	+	+
<i>Centropages laevigatus</i>	+	+
<i>C. phlegosoma</i> *	+	+
<i>Platycopus intermedius</i>	+	+
<i>Pseudoserratula californica</i>	+	+
<i>P. albarump</i>	+	+
<i>Heliosperma petriicola</i> *	+	+
<i>H. sylvatica</i>	+	+
<i>Hydropluteus insularis</i>	-	+
<i>Paraquadrula globulosa</i>	+	+
<i>P. irregularis</i>	+	+
<i>Laeonereis affinis</i> **	+	-
<i>Oceanic and volcanic islands, tropical forms</i>		
<i>Centropages laevigatus</i>	+	+
<i>C. stenodiplandriana</i>	+	+
<i>Cyclopoides intermedius</i>	+	+
<i>C. labilis</i>	-	+
<i>C. laetionoma</i>	-	+
<i>C. asperifolius</i>	-	+
<i>Reoporeula humicola</i>	+	-
<i>Apocaris reticulatissima</i>	+	-
<i>Quadrulella trispina</i>	-	+
<i>Forma-characteristic for soil and under human types</i>		
<i>Cyclopoides ambigua</i>	+	+
<i>Neopanopeus arcuata</i>	+	+

\* Species include, respectively, *C. phlegosoma* var. *terrestris* and *Heliosperma petriicola* var. *antithetica*, *H. petriicola* var. *humicola*. \*\* Species belonging to the tropical forms.

1. Actually some trophically active cells occur in water suspension and in other samples from stalk (14, 15, 16, 20).



but due to their low number their proportions was not estimated. Coconut waste in different stages of decomposition, arranged around the perimeter of the crown, served as fertilizer. The testacean communities did not differ significantly from natural variant and contained up to 10 species, whereas their abundance was three times as high as that of un-fertilized soil (about  $2 \times 10^3 \text{ g}^{-1}$ ).

**GRANITE ISLANDS.** In primary and secondary forests of larger mountainous granite and gneiss islands the species diversity and abundance of protozoans were higher (Tables 2, 3). Mahe was noted for humified brown tropical soil in fissures of granite blocks (secondary forest with *Cratogeomys*), where testacean communities were most diverse, containing almost 50 species. Along with eurybionts, there were ecological group of bryophils (*Nobela*), pedobionts (*Plagiopyrus*), etc., as well as all the tropical species recorded in the present study. In the same site (sample 4) the maximum numbers of  $73 \times 10^3 \text{ g}^{-1}$  was recorded, due to the intensive development of *Phryganella parvulus*.

On Silhouette and La Digue the communities were diverse (30-35 species) and abundant (about  $25 \times 10^3 \text{ g}^{-1}$ ) in litter, substrate in leaf axils of *Lodicea*, humid moss epiphytic growths on trees in primary and secondary wet tropical forests. The communities consisted of eurybionts, representatives of the tropical group, as well as small filose *Euglypha* and *Thysano* species (e.g., in sample 31 over 50% of the total number), which were rather scarce or entirely absent in stoll biotopes.

The species composition of living shells in forest soils, litter and other substrata of granite islands was much richer. In addition to those, listed for stolls, they were found in populations of *Centropyge anophala* var. *sphaeriscula*, *C. casta*, *C. constricta*, *C. plagiatorum* var. *terricola*, *Cyclopyxis ambigua*, *C. ductis*, *C. eurytoma* var. *gambitiana*, *C. asaphanotoma*, *Plagiopyrus declivis*, *P. declivis* var. *oblonga*, *P. intermedia*, *Phryganella parvulus*, *Nobela collaris*, *N. lageniformis*, *Rhyolosphemia nitida*, *N. rubiflava*, some *Euglypha* and *Thysano* species. The fact shows more active life status of these populations in high islands habitats.

On La Digue island, apart from the forest soil, some samples were taken in an Agricultural station. In compost heaps only a few eurybionts occurred (*Cyclopyxis eurytoma*, *Euglypha* spp.), while in soils of a cabbage field there were 16 species. This was a set of widely distributed forms without clear dominants, including *Trigonopyxis arcuata*, *Cyclopyxis ambigua*, typical of coarsely humified substrates (mod - moder type humus).

## Discussion

Data on protozoans in Seychelles and other islands, adjacent to the coasts of Africa, are very scarce. Deckerle (1956, 1959) was the first to publish a list of 50 testacean species inhabiting water bodies, meadows and lichens of Madagascar (up to 2400m altitude), comparing it with equatorial Africa and Seychelles. In particular, the absence in Seychelles of some common species was noted, the fact resulting, in my opinion, from inadequate and irregular studies, rather than from actual faunistic differences: some such species (widely distributed *Centropyge anophala*, *Cyclopyxis eurytoma*, *Heteropora petricola*, etc.) were found in the present samples.

In compost (Mauritius) 12 species and varieties of Testacea were found by Henney & Chander (1988). Such media were considered by the authors as favourable habitats for Testacea, the fact was stressed as especially important for tropical and subtropical regions, where com-

poor often develops naturally. Rapidly ripening compost, investigated in the present study in La Digue (coconut waste, manure), contained only 3 species. This can probably be related to differences in composition and ripeness.

Having analysed samples of moss and bottom sediment of ponds in Mahe (Seychelles), Wiles (1912) recorded over 40 testacean species. Most belonged to *Nichea* and *Euglyphis*, thereby pointing to the prevalence of bryozoans and hydrozoans. Some new forms were described, of them *Quadracella trojana* was revealed in our material.

I have found 23 of the species recorded by Wiles (1912). As there were no permanent water courses in the areas studied, our collections contained practically no hydrozoans (*Euglyphis* and *Arcella* were very rare). On the other hand, no Tenuacea, inhabiting low coral islands, were found in the list composed by Wiles. The main feature of atoll ecosystems is coral sand and hence the abundance of substrate with excess free calcium. The group of species I recorded in atolls, according to Bonner's (1959) classification (who used phytosociological principles), were typical of the association *Hollisteria gracilis*, *Paradaweristocum calcicolum*, *Paraquadracella-Hyalospharidium* association, developing in biotopes with pH above 7, and having a great indicative value. Their pantropical distribution in the substrata of the same type was confirmed by our investigations of Pacific Ocean atolls (Korjagina 1985b) (Table 4). Representatives of the tropical group were not found in atolls (excluding calciphilous species *Paradaweristocella delavayae*), presumably due to the fact that in secondary forests on atoll plant litter is dry, not developed and often practically absent.

The list by Wiles (1912) indicated the species with limited range only among *Nichea*. In our collection some of *Nichea* were absent (e.g., *Nichea scalaris* Wiles), but generally the "southern" forms in our material were more diverse, both in species and genera. The number of such forms was always low, but due to their large size (*Cyclopyxis shufeldti* about 200 microns) their share in biomass is rather high.

The question of the specificity in testacean geographical distribution, firstly noted by Penard (1910, cited after Hoogmoed & De Groot 1979), has been widely discussed. As a result of intensification of protozoological investigations in the Southern hemisphere the group of some dentic species with a limited tropical range was distinguished in the last decades. The fact, that there are some protozoans, confined to particular large regions, is also proved for some infusorian species, occurring only in Australia (Houseman 1988) (cf. "tenuosum-australobionts", according to Jung, 1942). Some "Gondwanan" testacean families are considered as a separate line of evolution, developed as a result of continental drift (e.g., Jung 1942, Declaire 1973, Hoogmoed & De Groot 1979, Bonner 1979).

The other, ecological explanation of limited "southern" species range is the assumption that their expansion into northern regions is prevented by natural geographical barriers (the direction of water streams and winds, deficit of optimal media) (Chardar, 1963). It is possible moreover, that such forms are difficult to find due to their rarity in northern biotopes and their position in consumption as L-selected ("drow-ry") species, presented in minimal number (Whittaker 1980, Korjagina 1985a). I agree with the ecological explanation and consider, that the extension of zoogeographical investigations, primarily with respect to territory, can give new information concerning testacean distribution. Indeed, there have been some interesting and surprising finds of southern taxa in the Northern hemisphere made re-

cently (Bonnet & Gomez-Sanchez 1984, Wimmer 1991, Zaidadov 1991, Bobrov 2000). Bonnet & Gomez-Sanchez explained the facts by ancient contacts of the Iberian peninsula with south end of North America and with Central America, as well as the existence of common floristic elements and some forest refugia in Europe. It is clear, that the question of testacean world distribution is far from its final solution.

A considerable number of our samples (22 of 40) were collected on coral atolls. If we follow Jung (1942) in considering the samples as optimal (1-6, 27-34, 36-40) and unfavourable, extreme and even aggressive media for protozoans (5-26, 35) (even though the separation is not strict) it is the samples from atolls which belong to the latter. The soils in such small flat pieces of land are unstable habitats readily affected by climatic fluctuations, in particular by intensive drying. For instance, the annual dryness index (the ratio of evaporation to precipitation) on Assumption is as high as 2.0, as against 0.95 in coastal parts of Silhouette and even 0.77 on its summit. Nevertheless, in atolls we found a moderate species diversity in a distinct calcophilous complex (Bonnet 1973, Korganova 1985b) which characterised the atoll's testacean population. It is composed chiefly of stenobionts-calcophiles, with the addition of some species tolerant of high salinity and some eurybionts. According to our observations, the latter were *Quadrulidia symmetrica*, *Helopora sylvatica* and *Parasquadrula irregularis* and *P. globulosa* (the only species, found in soil from a cliff, with 100% of cells being trophically active, see Korganova 1985b). Being found in algal banks in Parqhuat, they demonstrated the highest resistance to wave action and, in Assumption substrata, to high dryness: the living cells were recorded even in such dry samples as crusts of algae. Other species were found as single specimens.

Extreme habitats like carbonaceous soils can be compared with arid soils in steppe plots of Mongolia (Korganova 1990) where conditions of over-dryness (field humidity as low as 1%) and mobility of upper horizons (sohan mounds) approach the survival limit for trophically active protozoans. Only 1-2 *Euglyphis* and *Dremona* species in extremely low number (less individuals g<sup>-1</sup>) were found; unlike to atolls, there were no calcophilous species in Mongolian steppe soils.

The species recorded on atolls were mostly rather small, common forms with simple test morphology, lacking any special adaptations to soil conditions. However, in contrast to Jung (1942), who defines testacean communities in extreme habitats as being not ecologically specific, in our material they are highly specific, having at least seven stenobiont characteristic species (even more than in optimal habitats, Table 5) restricted to biotopes with high pH. This calcophilous association, typical of atolls, belongs to *Leborea*, *Filosea* being at a minimum, therefore the ratio of *Filosea/Leborea* is lower than in optimal habitats and the average value for the entire material (21.2%).

Analyzing ecological features of representatives of the genus *Plagiodon*, Bonnet (1988) outlines stable habitats populated by *K*-selected species and non-stable ("aggressive") habitats rich in *r*-selected forms. To the latter the author attributes *P. aspersus* - a common soil species, preferring the xerophilous media with higher CaCO<sub>3</sub> content, the fauna accompanying it is poor in *Filosa*. The characteristic in most of the situation in low atolls of Seychelles, where *P. aspersus* is not abundant, but permanent in associations of fringing carbonate soils (Table 4), *Euglyphis* and *Dremona* being rare and low in numbers. Lafroniger et al. (1983) defined some infusorian species (Colpodea) as *r*-selected, the fact might explain their

wide distribution in unfavorable territorial habitats

There were no *Nichele* species, a typical element of the bryophilous complex, in coral groups from atolls. *Nichele* species avoid media with pH higher than 7, their absence is related to the fact that all the habitats in atolls (even meadows) are influenced by coral sand, and the soil pH is about 8 (Thudgill, 1979). At the same time, in epilithic mosses on the granite island of Silhouette *Nichele* species, including living cells, make up a considerable portion of the numbers - over 30% in sample 30.

Species diversity, the main faunistic quantitative and structural parameters of communities, in optimal habitats of granite islands (especially in mountainous forests) are considerably higher than those of extreme habitats (e.g., the average number of shells is higher by an order of magnitude, Table 5). The much wider range of habitats in moist tropical forests gives the opportunity for colonization by many different testacean ecological groups, as well as by tropical species, for which such forests represent typical habitats (Borner, 1977a).

Protozoan colonization of small islands, remote from large land masses, faunal composition and chronology on islands of different size and origin have been discussed in detail for Pacific islands (Koganova, 1983a, b, c). It is interesting to compare these investigations with the results of the present study. The main ecological features of tropical islands of reef origin (excess free calcium) and granite or volcanic ones (large areas of primary or secondary forests with humified light soils and specific "tropical" substrata) are to a great extent similar in both regions. Accordingly, there is a certain similarity of faunal structure of Pacific and Indian Ocean islands: most of the fauna consists of representatives of Ctenophoridae, Hydrophoridae and Euphyllidae families (about 90%). They comprise a complex of widely distributed forms, supplemented in the islands of both oceans by some tropical forms. 11 tropical species were found altogether. Practically all were in mountainous forests (soil, litter and meadows) in granite (Seychelles, Indian Ocean) and volcanic (Tonga and Western Samoa, in the Pacific Ocean), but their combinations were different. Representatives of calciphilous complex, being stenobionts, showed pantropical distribution. One more complex, which can be distinguished in the material, collected on all the islands, included *Cyrtogaster ambigua* and *Trigamagaster areola*, inhabiting "suspended soils" and substratum under epiphytes (i.e. moss - mossy type fungus). Thus, the characteristic testacean complexes (disregarding eurybionts) were quite different in three habitats types, but had great similarity in pantropical biotopes (Table 4).

Table 5. Parameters of Testacean community structure in extreme and optimal habitats

Parameters	Extreme habitats	Optimal habitats
Total number of species in group	37	64
Range in number of species in communities	1-20	6-48
Average abundance in group, $\pm 10^3$ g <sup>-1</sup> oven-dried substratum	1.7	11.9
Number of genera	15	15
Genera number *	28	56
Percentage of large species, % **	2.7	0.9
Number of communities with more than one "southern" form	0	5
Number of communities with more than one diatomitic form	7	5
Filixen species, %	19.7	23.8

\* The number of species divided by the number of genera. \*\* Small - about 50, large - about 100 microns.

We characterized protozoan fauna on Pacific islands as, to a certain extent, impoverished in comparison with the continental one - the source of species distribution. Not only some species, but also families (such as Arcellidae and Diffugiidae, widely distributed in Europe) were shown to be virtually absent. The absence of these families is noted in the present study as well. Furthermore, Euglyphidae are poor in genera (there are no *Amphies* and *Corythos*, which are especially abundant in coniferous forests of Eurasia, pers. obs.). Such "defectiveness" is a peculiar characteristic of the macrofauna of remote islands and in biogeographical studies is traditionally explained by difficulties of colonization due to isolation and lack of space. For microscopic and easily dispersed Testacea we consider as highly important not such "external" factors, but the "internal" factors - the scarcity or lack of optimal biotopes<sup>2</sup>, in particular of permanent water bodies (main habitats of *Arcella* and *Diffugia*). Tropical moist primary forests with their great habitat variety present stable media with high and stable humidity (up to 100% in high moss hummocks on volcanic craters, Kerguelen 1985b), favourable for development of all testacean ecological groups (hygrobionts, geobionts, litter inhabiting forms, hydrophiles, etc.) and are densely populated by protozoans.

## Conclusion

Testacean (Protozoa) populations have been studied in different substrata (soil, plant litter, mosses, suspended soils, local human accumulations and algal barots) in low (Farquhar, Porvre) and elevated (Assumption) islets and granite islands (Silhouette, Félicité, Mahé and La Digue) of the Seychelles Archipelago. 94 species and intraspecific taxa were recorded, biomass reaching  $0.65 \text{ g m}^{-2}$ . The presented list more than doubles the number of testacean species, known for Seychelles. The main part of the fauna consists of ubiquitous species of various ecological groups, supplemented by tropical forms. The diverse species composition and high numbers were observed in the substrata of primary and secondary tropical mountain forests in granite islands, having stable humidity and high humus content. The species composition in islands of reef origin is not rich, and is uniform, irrespective of the location of the island, being determined by the prevailing habitats with excess free calcareum. A certain "defectiveness" of the fauna (poor representation of Arcellidae and Diffugiidae) as compared with the mainland are explained by the absence of favourable habitats. Spatial distribution of allochthonous unicellular shell amoebae in insular biogeocoenoses demonstrated an uneven dissemination, dependent upon the substrata, optimal for the definable protozoan ecological groups (Kerguelen 1999) and is similar to testacean communities in the Pacific Ocean.

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<sup>2</sup> Occasional desertification patterns can also be observed, e.g. colonization of a limited substrate by a species (here a dense population of *Phryganella parvula* in a dead trunk, in nearby forest soil only single specimens found).

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## A note on the butterflies of Cousine Island, Seychelles

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## Introduction

No information has been published on the butterflies of Cousine island, and the records given are those collected from 1995 to 1999. Cousine Island is a small (26ha) granitic island rising to just over 70m above sea level and lies at 4°29'41"S and 55°38'44"E. The vegetation and general characteristics have been described in Bourquin (1996).

Common diadem *Hypolimnys eurypus* (Linnaeus, 1764)

The common diadem butterfly (*Hypolimnys eurypus*) is widely distributed through the greater part of the Indo-Australian region, a part of the tropical and subtropical Americas, the Afrotropical region and in Seychelles (van Son 1975). Its food plants include *Asystasia gangetica* and *Portulaca oleracea* (Pringle et al. 1994, de Nolet 1984). Both the food plants are common and wide-spread on Cousine Island (Bourquin 1996). The male is black with two oblique elongated white spots on each forewing and a large white spot on the hindwing. The female is orange with black and white patterns on the wings, much resembling an African monarch (*Danaus chrysippus*) for which it is often mistaken. The females show several colour patterns, varying in the degree of black and white markings.

The adults appear suddenly, numbers increasing either rapidly (within a few days) or peak in numbers over a few weeks. They may be seen flying for between a week and a month and a half before disappearing.

During 1996, the first adult was noted on Cousine on 29<sup>th</sup> March at 05h00, resting on a tree branch. An estimated ratio of 1 female to 4 males was observed during the day. One pair was seen in copula. Predominating winds during the preceding few days were north-west and since no butterflies were observed during this period, it is believed that a mass hatching took place on the night of the 28<sup>th</sup> or morning of the 29<sup>th</sup>. Some 95mm of rain had fallen between the 27<sup>th</sup> to 29<sup>th</sup> March, prior to which no rain had fallen for a week and temperatures were high. Butterfly numbers declined rapidly after a week and they had disappeared entirely by 14<sup>th</sup> April. During 1997, the butterflies appeared on 18<sup>th</sup> March with the last record being on the 11<sup>th</sup> April. Following heavy, unseasonally early rains in August 1997, the butterflies appeared on 17<sup>th</sup> December and had disappeared by the 12<sup>th</sup> January 1998. They appeared again on 19<sup>th</sup> March and were gone by the 30<sup>th</sup> April 1998. On 29<sup>th</sup> March 1999 the first common diadem butterflies of the season were again noted, but in very low numbers. No sightings were recorded after 5<sup>th</sup> April. During their brief appearances copulation was observed.



On Anse Island, similar events have been recorded (Bullock 1989, Bowler & Hunter 1999). During 1988 the species was seen between 20<sup>th</sup> February and 26<sup>th</sup> March, and again on 19<sup>th</sup> November. In 1989 they flew from 20<sup>th</sup> May to late April and in 1998 they were seen between 15<sup>th</sup> March to 31<sup>st</sup> April.

It seems therefore that on other islands the adults appear at much the same time and stay for the characteristically short periods. Are the butterflies permanent residents on the small Seychelles islands? If so, then mass synchronised hatching of the pupae following required climatic conditions must be taking place. The possibility also exists that the butterflies hatch on larger islands and are blown onto the smaller ones. This is unlikely since the butterflies normally appear during the end of the light, variable north-west monsoon winds (March) and during the calm period prior to commencement of the stronger south-east trade winds (April). There are great distances of open ocean to the north-west of Cousine Island, the nearest islands being Cochin and Fralin, a few kilometres to the north-east.

The rainfall for Cousine is highest during January and February, immediately preceding the butterflies' appearance, but when unseasonably high rains occur (as during August 1997), the butterflies may appear during early summer, indicating a flexibility in adapting to favourable rainfall conditions. We assume that the rainfall effect is one which spurs food-plant growth rates, therefore creating suitable conditions for larval growth, and triggering mass adult emergences from the pupae. The butterflies are therefore considered to be permanent residents on the islands. As such, it would be interesting to see if any genetic traits have developed for individual islands.

#### **Painted lady *Speirops carchas* (Linnaeus, 1758)**

The painted lady is a widespread butterfly in north America, Africa and some Indo-Pacific regions (Pringle *et al.* 1994, Pyle 1996). A gravid female was collected on 3<sup>rd</sup> April 1996, while one other specimen was seen on the same day. Subsequently no further painted ladies were seen until January 1998, when another gravid female was found. More were seen between 29<sup>th</sup> March and 7<sup>th</sup> April 1998. The species appears during roughly the same time as the common diadem. Food plants include members of the Boraginaceae, Compositae and Malvaceae (van Son 1979, Pringle *et al.* 1994), of which 7 representatives are found on Cousine (Bourquin 1996).

#### **Lucerne blue *Lampides boeticus* (Linnaeus, 1767)**

Five specimens of the lucerne blue were seen during 14<sup>th</sup> and 15<sup>th</sup> March 1998. The species is widespread in Africa and the western Indian Ocean islands (de Nisi 1984), and extends into Europe and most of the warmer parts of the East. The food plants are legumes including a wide variety of genera (Pringle *et al.* 1994). Legumes are not common on Cousine, being represented by one tree, one climber, one creeper and two subshrubs (Bourquin 1996).

#### **Sooty blue *Zizys argyrea* (Trimen, 1862)**

The sooty blue is wide-spread in Africa, western Indian Ocean, Spain and southern Arabia and is a common and permanent inhabitant on the open flat areas of Cousine, flying around low growing plants and seen during all months of the year. Known food plants

include *Anacanthus* spp. and *Elaphochia* spp. (Pangile et al. 1994), both genera being represented on Cousine by one and three species respectively (Bourquin 1996)

(olive-haired swift) *Borbo borbonica* (Boursani, 1833) morella (Jeannel, 1893)

The olive-haired swift is widespread in Africa and is found on the Indian Ocean islands (de Nolet 1984, Henning et al. 1997). It is seemingly scarce on Cousine, but has been seen from October to April, usually near the edge of *Psidium/Ficus* forest and open areas. The species is a very swift flyer, and is dark brown with a row of white spots across the forewing. The food plants include various grasses (Henning et al. 1997) of which 20 species have been recorded for Cousine (Bourquin 1996)

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## NOTES

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### On the first captive breeding of the Seychelles black mud turtle *Pelusios subniger parietalis*

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The granitic islands of Seychelles are the most isolated islands to support natural populations of terrapins. Two species are present, both represented by endemic subspecies: the yellow bellied mud turtle (*Pelusios astimaculus* Hewitt, 1931) *intergalanus* Boer, 1983) and the black mud turtle (*P. subniger* (Lacépède, 1788) *parietalis* Boer, 1983). There is

some uncertainty whether or not a third taxon, *P. nycthellensis* (Seabroock, 1996) is an endemic species or a variant of *P. costaeoides*.

Of these species *P. nycthellensis* appears to be extinct (at least as a pure bred form) and *P. costaeoides intergalensis* and *P. ruberger parvula* are critically endangered, both being reduced to some 200 individuals (Gerlach & Canning, in prep.)

*P. costaeoides* and *P. ruberger* have been the subject of a captive breeding project by The Nature Protection Trust of Seychelles since 1997. This aims to produce juvenile terrapins for reintroduction to secure reserve areas. On 2<sup>nd</sup> January 1999 9 eggs were found in the *P. ruberger* pond, these measured 15.4-16.8×29.5-32.3mm. They had been in the water for an unknown period of time and none were viable. A further 11 eggs were found on 28<sup>th</sup> February, 9<sup>th</sup> March, 31<sup>st</sup> March, 7<sup>th</sup> April and 9<sup>th</sup> April. These measured 8-23.5×31.5-37.6mm. Of these, an egg laid on 28<sup>th</sup> February was still viable when found. This developed to within a fewer than 12 days of its estimated hatching date before a rat broke into the incubator and killed it. The corpse of the almost full-term embryo measured 23.5×18mm.

The enclosures were rebuilt in 1999 to encourage the terrapins to lay their eggs on land. In January 2000 a clutch of 8 eggs was again found in one of the *P. ruberger* ponds. These had been eaten by one of the terrapins and the gravid female was removed to a shallow pond where she could be monitored and kept in isolation. On 15<sup>th</sup> January a single egg was found in the pond at 19.30hrs, further eggs were found at 21.40, 22.00, 22.30 and 00.10 on 16<sup>th</sup> January. The last egg was found at 06.30hrs. A further two were subsequently found in the pond on 20<sup>th</sup>-21<sup>st</sup> January and two found broken on the soil surface on 26<sup>th</sup> January.

The eggs laid on 15-16<sup>th</sup> January were removed as soon as they were found, rinsed in clean water and placed on a vermiculite substrate in an incubator. Incubation was at 31°C and almost 100% humidity. Of the eggs laid in the water 2 showed signs of embryonic development after 11 days.

On 3<sup>rd</sup> March, after 47 days incubation one egg started to hatch at 07.30hrs, taking 10 hours and 15 minutes to hatch. On hatching the terrapin weighed 5g and measured 25mm long and 21mm wide. The yolk sac was still present, being 7mm diameter. Within 2 hours this had reduced to 3mm, and being almost fully absorbed within 6 hours.

During the first night the terrapin was left in the incubator and buried itself just under the surface of the vermiculite. It was moved to an a tank containing 5cm of water and a rock. After 5 minutes in the water it was swimming actively (Fig. 1) and feeding on small flakes of commercial terrapin food.

The second egg did not hatch. It was opened on March 26<sup>th</sup> and was found to contain a dead almost full-term embryo. By 22<sup>nd</sup> March (19 days after hatching) the hatchling had grown to 33×28mm and weighed 7g and by 9<sup>th</sup> April (37 days after hatching) had reached 38mm and 11g (Fig. 2).

From the 4<sup>th</sup> March until 7<sup>th</sup> May the hatchling was fed 3-4 pellets once a day. As there had been no weight gain since 16<sup>th</sup> April, feeding was increased to twice per day with a total of 8-10 pellets. By 5<sup>th</sup> June the yolk sac scar had almost disappeared. Skin shedding around the neck was apparent every 3-4 weeks.



Fig. 1. Hatchling *Pelusio subregeri parietalis* at 36 days.

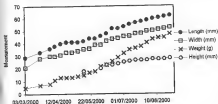


Fig. 2. Growth in *Pelusio subregeri parietalis* hatchling.

## NOTES

Toxicity of 'specific' rodenticides and the risk to non-target taxa

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Alien predators are known to have had devastating impacts on some island snail populations, most obviously in the introduction of the carnivorous snail *Euglandina rosea*

(Fénelon, 1821). Predation by rodents has been blamed for declines in many island animal populations, including snails. The most serious impacts have been described from New Zealand and there considerable expertise has been developed in rodent eradication techniques using anti-coagulant baits, the currently favoured poison being Brodifacoum. There have been few published studies of the impacts of rodent control on invertebrate faunas but there are reports, at least anecdotally, of increases in mollusc populations following poisoning campaigns (D. Merion pers. comm.).

In 1999 proposals were made for the eradication of rats from 5 of the Seychelles islands using Brodifacoum. Most of these islands are small and are not believed to retain significant endemic faunas (although this has not been investigated). The exception is Frigate island which supports several endemic species including the Frigate end snail *Pachyostoma fregataense* Van Mol & Coppens, 1980. The proposals included measures to protect non-target vertebrates, principally birds, but not invertebrates. The apparently unknown risks to invertebrates prompted an investigation of the effects of Brodifacoum on snails, insects and millipedes.

As was expected, all species would consume the bait and no adverse effects were apparent in any of the arthropods. In contrast, the snails suffered 100% mortality in the two species tested: *Achatina fulica* (Bowdich) and *Pachyostoma subaenariense* Van Mol & Coppens, 1980 (a common species used as a model for the threatened *P. fregataense*). The fatal dosages vary according to the size of the snail, for the 15–20mm *P. subaenariense* doses of only 0.01–0.2mg were sufficient to cause death within 72 hours.

Maussian field data support these observations. In the Brice For forest some 24ha has been subject to rodent control by poisoning. A number of snail species have been seen feeding on poison baits and in treatment areas statistically significantly higher numbers of “fresh” dead *Pachyostoma bicolor* and lower numbers of live adults have been found. Whether or not poisoning represents a significant threat to the affected populations depends on how this mortality compares with predation levels from mammals targeted by the poisoning. For the *P. bicolor* populations poisoning is a significantly greater mortality factor than predation, this site has the largest remaining *P. bicolor* population and is the only site for the critically endangered *Drypis nyctodon*, shell of which have also been found at the poisoning site.

These studies demonstrate that molluscs can be affected by Brodifacoum poisoning. The authors believe that the impact of such rodent control measures should evaluate probable impacts on molluscs and other invertebrates before implementation. Whether such poisoning is a serious novel threat to the mollusc populations will depend upon the precise levels of predation by the targeted rodents and the level of poisoning risk. In the Frigate island case, *Pachyostoma fregataense* has not been affected by the high population of brown rats but will readily consume poison bait and poisoning mortalities are expected to be high. Far more serious is the threat to a streptelod discovered in 1999. This is a mole-earl canon feeder which is likely to be attracted to the poisoned snails and to be killed by secondary poisoning. The significance of these findings is now becoming more widely appreciated, they have been taken into account during the implementation of the Frigate rat eradication (D. Merion & J. Nevill pers. comm.) and similar research is now being carried out as part of a review of Brodifacoum use in New Zealand (J. Booth pers. comm.).

## NOTES

### Note on the flower scarab *Oxytanta versicolor* (Fabricius, 1775) (Coleoptera: Scarabaeidae: Cetoniinae) in the Seychelles

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#### Introduction

The beetles known popularly as flower scarabs or flower chafers are sometimes treated as a family in its own right, the Cetoniidae (e.g. Krikken, 1984), but most authorities still treat them as a subfamily, the Cetoniinae, within the family Scarabaeidae (e.g. CSIRO 1991). The distribution of the four species known to occur in the Seychelles is summarised in Table 1. They are oval, rather flattened beetles measuring 3 mm or more in length and 4.5 mm or more in width, with a metallic sheen and/or striking colour patterns. They are usually found on vegetation, feeding on the nectar of flowers or the juice of ripe fruit, or resting on foliage. A detailed report on the Cetoniinae of the Seychelles is in preparation. This note (1) provides an identification key to the species, (2) reports on the fact that recent research has revealed a wider range for *Oxytanta versicolor* in the Seychelles than was hitherto known, (3) draws attention to the presence of a new colour form, and (4) suggests that during the period November 1959 - May 2000, *O. versicolor* suddenly became unusually "noticeable" if not actually more abundant on the island of Mahé.

#### Identification key to the flower scarabs of the Seychelles:

- |    |  |                                 |
|----|--|---------------------------------|
| 1a | Not shiny, white on pronotum restricted to a narrow lateral border on each side, a white dot on tip of scutellum                       | <i>Oxytanta versicolor</i>      |
| 1b | Shiny, relatively large white patches on pronotum, not limited to narrow lateral border on each side, no white dot on tip of scutellum | 2                               |
| 2a | A large irregular patch on each side of the pronotum, each enclosing a small black spot  | <i>Prosmena versichelica</i>    |
| 2b | Six white patches on pronotum  | 3                               |
| 3a | 11 mm or more in length, fifth abdominal segment with a rounded tooth on each side below   | <i>Monoctenopsis alabasteri</i> |
| 3b | Less than 11 mm long, no teeth on fifth abdominal segment  | <i>Oxytelus alabasteri</i>      |

#### New records

*Oxytanta versicolor* (Fabricius, 1775) was first reported from the Seychelles (as "*Glycyphana versicolor*") by Fairmaire (1893), who gave no locality data for the specimen (or specimens?) he examined. Brauer collected it on a farm at Maudslayi on Mahé in 1895 (Kolbe 1910). In 1917 Dupont found it on Mahé "attacking rose bushes in the daytime" (data with specimen in Dower G25 in the Natural History Museum, London).

The Seychelles locality data in Table 1 are based mainly on Scott (1912) reporting on specimens collected by the Percy Sladen Trust Expeditions of 1905 and 1908-1909 to the Indian Ocean. However, Mahé is the only locality in the granitic Seychelles mentioned by Scott. To this we must now add Silhouette and Praslin.

On July 24th 1990 (late morning - exact time not recorded), during the Oxford University Expedition to Silhouette, I observed a small "bail" of this species fall from an unidentified tree near the Grande Case at La Pisse. It consisted of at least five specimens of *O. versicolor* holding onto one another, possibly a case of several males attracted to a female. Unfortunately, the beetles scattered and most of them flew away before they could be examined more closely. On subsequent trips to Silhouette, this species was observed at La Pisse roosting between the terminal leaves of a shoot of an unidentified citrus (*Citrus* sp.), alighting briefly on a leaf of a breadfruit tree (*Artocarpus albus*) and feeding on the flowers of "vivy fly" (*Lantana camara*). On 6th August 1996, during the Oxford University Wetlands Expedition to Silhouette, I found a dead specimen on the beach at Grand Barbe.

Until 1999, I never encountered *O. versicolor* on Mahé, although it had been found there by various collectors, as indicated above. It must have been rare or "secretive" in its habits. In 1999 the species was recorded for the first time on Praslin. It was subsequently observed on several occasions on Mahé, and at the same time it was realised that a new colour form had made its appearance in the Seychelles.

Arrow (1910) treated as "phases" or "varieties" of *O. versicolor* what previous authors had described as separate species. His "var b" is characterised by being opaque with "red" (actually reddish brown) on the prothorax (except for a pair of large black discoidal spots) and the middle part of each elytron, with white markings. According to him, this colour form is to be found in India, Sri Lanka and Mauritius, while Scott (1912) refers to a specimen that was collected in the Chagos islands. Arrow's "var d" is characterised by being entirely black and opaque, with white markings, and is mentioned as being found in Sri Lanka and Mauritius.

All specimens collected in Seychelles up to 1999 are of the form described by Arrow (1910) as "var d" (= *Catantia variegata* Fabricius, 1775 = *Catantia lacteum* Gory & Pouchon, 1833). On 31st October 1999 Justin Gerlach found a specimen of "var b" in the swimming pool of the Bergaya Praslin Beach Resort at Anse Volbert on Praslin. This specimen (NPTS Hel 999 96) is now in the collection of the Nature Protection Trust of Seychelles. The following data are for Mahé:

15th November 1999 Rosemary Mathias collected a specimen of "var d" on *Moringa oleifera*

Schlage at La Rosière on Mahé

9th January 2000 In the same locality I discovered a specimen of "var b" that had just been

Table 1. Distribution of *Catantia* in the Seychelles

G = Granitic islands, C = Coralline islands

Species	Distribution in Seychelles	Distribution elsewhere
<i>Proctosia maculipes</i>	G Mahé, Silhouette, Praslin, Morillon, Pâques	India, Mauritius, Réunion
<i>C. fabricei</i> (Fabricius, 1775)	C Anse-aux-Diables (Domenach, Reunion), Denis	
<i>Catantia versicolor</i>	G Mahé, Silhouette, Praslin	Sri Lanka, Chagos, Madagascar,
(Fabricius, 1775)	C Anse-aux-Diables (Domenach, Reunion), Coëtivy, Farq	Mauritius, South Africa
<i>Oxythyrus obdabrensis</i>	C Aldabra (Ponard), Comoriles	
Linell, 1957		
<i>Microthyrus obdabrensis</i>	C Aldabra, Anse-aux-Diables, Comoriles,	West Island (Lopez)
Linell, 1957	St. Pierre, Tromelin*	(Scott 1912)

\* if *Microthyrus pseudofabricei* Linell, 1957 (Scott 1912) then *M. obdabrensis* male (suggested by Scott 1912)

trapped in a web of the spider *Nephila maculosa*, close to an *Anacardium occidentale* tree on which I had previously found the other flower scarab of the granite islands, *Proconia aeneolus*.

30th January 2000 I found another specimen of "var. b" in the same web!

1st March 2000 At 10 a.m. three scarabs were seen on a branch of green pods on a flamboyant tree in the grounds of the Youth Centre at Mont Fleury. Since they were quite high overhead, it was not possible to ascertain that they were *O. versicolor*.

3rd March 2000 At around 7.30 a.m., I observed a number of flower scarabs circling above the carambola tree mentioned above. A *Seychelles* bulbul *Hypsositta carinatus* was flying to and fro among them, catching them in its beak with a loud cracking sound. Again, it was not possible to establish if the beetles were *O. versicolor* or *P. aeneolus*.

18th March 2000 At 3 p.m. I found a specimen of "var. b" and one of "var. d" resting on the foliage of two *Nerium oleander* bushes in front of the National Library in Victoria.

6th May 2000 I found a specimen of "var. d" resting on a compound leaf of a *Leucaena leucocephala* bush at Anse Nord-Est at 12.15 p.m.

The above observations raise the following questions:

1. Is *O. versicolor* more numerous than it used to be or is its recent "obtuseness" on Mahe due to some other factor?
2. Why does this apparent increase in numbers coincide with the appearance of a colour form that up to the end of 1999 had not been recorded from Seychelles?

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## NOTES

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### The rediscovery of the Seychelles hummingbird hawkmoth *Macroglossum alluaudi* Joannis, 1893 (Lepidoptera: Sphingidae)

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Two species of hawkmoth have been described as endemic to Seychelles. One, the Seychelles tree hawkmoth, *Cephalodes torni* Giraud, 1960, was rediscovered after 92 years (Gertsch 1998). This species remains known from the type specimen from Mahe and a small extant population on Silhouette. The second endemic species, the Seychelles hummingbird hawkmoth *Macroglossum alluaudi* was described from two female specimens from Mahe. The type specimen was collected by Charles Alluaud in 1892 and the second reared from a



larva by Philbert (this specimen is now lost - Legrand 1965). A third specimen is present in the Berlin museum but without any locality data (Legrand 1965). No further specimens were located despite searches by professional and amateur lepidopterists and the species has been considered as possibly extinct for many years (Legrand 1965, Gerlach 1997).

During a survey of the *Cyphomandra* native population on Silhouette in July 2000 an unfamiliar hawkmoth was noticed near the Dauban museum at La Plaine. This was captured and identified as *M. albanus*. The species was found at the same site on several occasions, always in the late afternoon. Its presence was recorded on 10th July (16:25hrs), 11th July (17:00hrs), 12th July (17:30hrs), 13th July (18:00hrs), 17th July (17:00hrs) and 26th July (17:30hrs). On each occasion only a single individual was observed. All individuals were seen feeding on *Lantana camara* flowers alongside *C. aurea* and *C. hylax* Lemaire, 1771.

As with the bee hawkmoth population, it is probable that the *L. camara* flowers offer a larger nectar source than most of the native plants in the vicinity. Small populations of bee hawkmoths and hummingbird hawkmoths may survive in areas where *L. camara* provides a reliable nectar supply and where patches of high quality lowland vegetation survive. For the bee hawkmoths this is provided by the abundance of their larval food plant *Cassipouira abbreviata* at Point Varreut. The single recorded larva of *M. albanus* was reared on *Azadirachta indica* (Legrand 1965) which is also present in this area.

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Fig. 1. *Macroglantrum albanus*, Silhouette July 2000